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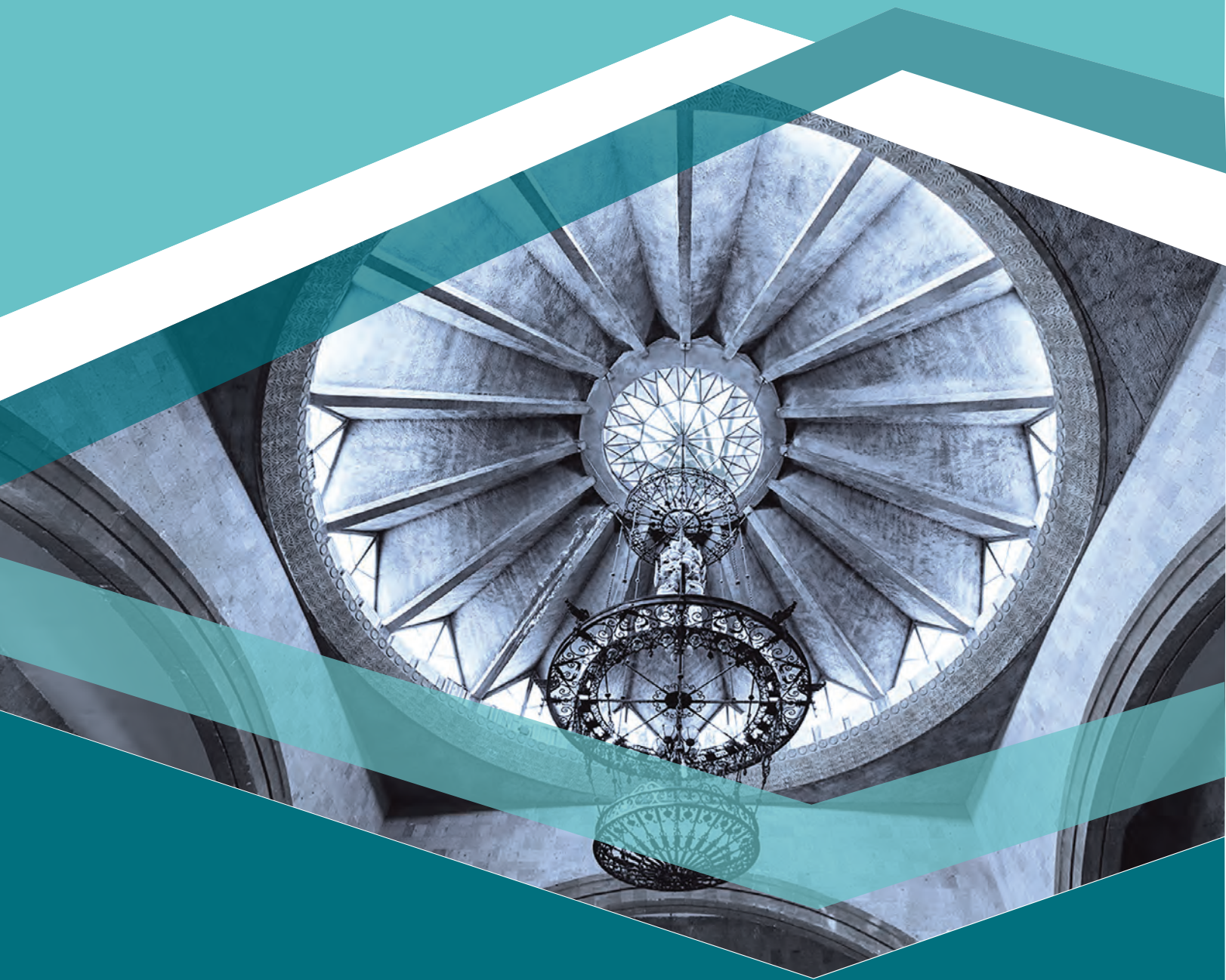

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CONTENT

THE COMPARISON ANALYSIS OF DEVELOPMENT LENGTH IN ACCORDANCE WITH ARMENIAN AND FOREIGN BUILDING STANDARDS

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Abstract: *The study of a development length determination according to Armenian and foreign building standards is presented. For analysis implementation different concrete classes (B20, B25, B30) and rebar diameters (25mm, 28mm, 32mm) were chosen. Reinforcement bar class A500C was taken. Two different cases were considered: in one case, the reinforcement is taken in tension, in the other case, in compression. The results show that in the cases of both tension and compression, the value of the anchorage length obtained by Armenian building standards is 23.1% more than by Russian codes received. In the case of tension, the value of the anchorage length obtained by American codes is 16.7-20.8% more than the one obtained by the Armenian building standards. Consequently, the anchorage length also should be checked by the American building standards for structure design.*

Keywords: *development length, anchoring, reinforced concrete structure, building standards, seismic design.*

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Introduction

Anchoring is a very important process on the correctness of which the quality, durability and ability to withstand various loads of the reinforced concrete monolith depends. Reinforcement reinforces concrete structure, to absorb and take the loads, to make the monolith durable, reliable and solid. Reinforcement elements can be rigid or flexible, and are usually made of steel or composite materials.

The size and type of anchoring is largely determined by the characteristics and operating conditions of certain areas where loads are transferred from the metal bars to the material. There are several methods of anchoring and it is important to carry out correct calculations beforehand by determining key parameters such as method of anchoring, length of reinforcement anchorage, etc.[1] [1,2, 11-13].

Provision of appropriate development is an important aspect of safe construction practices. Proper development length in reinforcement bars shall be provided as per the steel grade considered in design.

Otherwise in scenarios where less development length against the required is provided the structures will be prone to encounter failure due to slippage of joints, bonds, anchors and laps, in such cases the bars will not yield first but the failure will happen at joints and laps prior to yielding of reinforcement bars[2] [3,4].

The main purpose of the paper is to analyze the development length calculations, according to varies building standards and estimate the differences between them.

Materials and Methods

To implement the comparison analyses of development lengths (Fig.1) were chosen Russian and American building standards RA[3], RF[4], USA[5], inasmuch as given codes are widespread in the sphere. For future analyses the possible alternative standards will be included.

In accordance with Armenian current building standards "RA" the required anchorage design length of the

[1] https://1beton.info
[2] https://theconstructor.org
[3] Betone yev yerkatbetone konstruktsianer (nakhagtsman normer), HHSHN 52-01-21 (in Armenian).
[4] СП 63.13330.2018 Betonnyye i zhelezobetonnyye konstruktsii (in Russian).
[5] Building Code Requirements for Structural Concrete (ACI 318-19).

bar taking into account the constructive solution of the element in the anchorage zone, is determined by the following formula:

$$l_{an} = 1,3 \cdot \alpha \cdot \frac{R_s}{\eta_1 \cdot \eta_2 \cdot R_{bt}} \cdot \frac{A_s}{u_s} \cdot \frac{A_{s,cal}}{A_{s,ef}}, \quad (1)$$

where:

α is a coefficient that takes into account the influence of the stress state of concrete and reinforcement, as well as the constructive solution of the element in the anchorage zone on the length of the anchorage,

R_s is the design resistance of the reinforcement bar,

η_1 is a factor that takes into account the effect of the surface appearance of the reinforcement bar,

η_2 is a factor that takes into account the effect of the size of the reinforcement bar's diameter,

R_{bt} is a design resistance of concrete by axial tension,

A_s and u_s respectively, are the cross-sectional area of the reinforcing bar and the perimeter of its cross-section,

$A_{s,cal}$ and $A_{s,ef}$ respectively, are the cross-sectional areas of the reinforcement required by calculation and actually installed.

For non-prestressed reinforcement bar, when anchoring of bars with straight edges of periodic grid (straight anchorage) or without additional anchoring devices with staples or hinges of flat surface reinforcement, $\alpha = 1.0$ is taken for tensioned bars and $\alpha = 0.75$ for compressed bars.

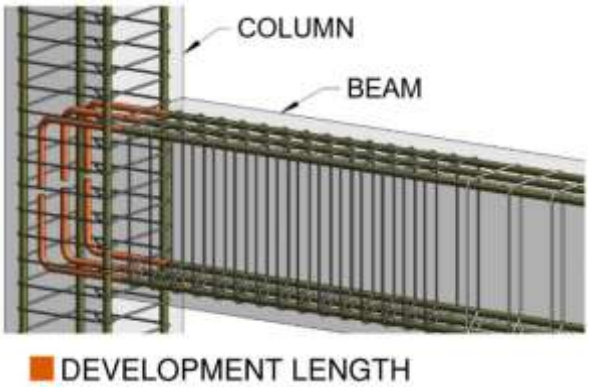

Fig. 1. *Scheme of development length*

For non-prestressed reinforcement bar the η_1 coefficient is equal to 1.5 in case of flat surface reinforcement bar, 2.0 in case of cold-deformed reinforcement with a periodic pattern and 2.5 in case of periodical grid - rolled and thermomechanical treated rebars. Moreover, for non-prestressed reinforcement bar the η_2 coefficient is equal to 1.0 when the diameter of rebar is less than *32mm* and is equal to 0.9 when the diameter of rebars are *36mm* and *40mm.*

In accordance with Russian current building standards "RF" the required anchorage design length of the bar, is determined by the following equation:

$$l_{an} = \alpha \cdot \frac{R_s}{\eta_1 \cdot \eta_2 \cdot R_{bt}} \cdot \frac{A_s}{u_s} \cdot \frac{A_{s,cal}}{A_{s,ef}}. \quad (2)$$

In all cases, according to the Armenian and Russian building standards, respectively the actual length of the anchorage is accepted not less than *25ds* and *300mm*, *15ds* and *200mm*, and for non-prestressing bars, also not less than $0.5l_{0,an}$ and $0.3l_{0,an}$, likewise the length of anchorage of reinforcing bars is allowed to be reduced depending on the number and diameter of the transverse reinforcement, the type of anchoring equipment (welding of the transverse reinforcement, curvature of the edges of the periodic bars) and the transverse compression of the concrete in the anchorage zone (for example, support displacement), but not more than *30%.*

The base (main) length of the anchor [5,6], which is necessary to transfer the resistance stress of the reinforcement to the concrete with the full design value, in accordance with the Armenian (3) and Russian (4) building standards, respectively is determined by the following formula:

$$l_{0,an} = 1,3 \cdot \frac{R_s}{\eta_1 \cdot \eta_2 \cdot R_{bt}} \cdot \frac{A_s}{u_s}, \quad (3)$$

$$l_{0,an} = \frac{R_s}{\eta_1 \cdot \eta_2 \cdot R_{bt}} \cdot \frac{A_s}{u_s}. \quad (4)$$

Design resistances of concrete according to axial compression (R_b) and axial tension (R_{bt}), are determined by the following formulas:

$$R_b = \frac{R_{b,n}}{\gamma_b}, \tag{5}$$

$$R_{bt} = \frac{R_{bt,n}}{\gamma_{bt}}, \tag{6}$$

where:
$R_{b,n}$ and $R_{bt,n}$ respectively, are the normative axial compression and axial tension,
γ_b and γ_{bt} respectively, are the reliability factors of concrete in compression and tension.

In the case of compression, the values of the concrete reliability coefficient are taken as equal:

1. the first group for calculation with limit states
   a. 1.3 – for heavy, fine-grained, tension and light concretes,
   b. 1.5 – for cellular concrete,
2. the second group is taken equal to 1.0 in case of calculation with limit states.

In the case of tension, the values of the reliability coefficient of concrete are taken equal to:

1. the first group for calculation with limit states, when the class of concrete is defined according to compressive strength
   a. 1.5 – for heavy, fine-grained, tension and light concretes,
   b. 2.3 – for cellular concrete,
2. the first group for calculation with limit states, when the class of concrete is defined according to tensile strength
   a. 1.3 – for heavy, fine-grained, tension and light concretes,
3. the second group is taken equal to 1.0 in case of calculation with limit states.

If necessary, the calculated values of concrete strength [7,8] characteristics are multiplied by the following coefficients of γ_{bi} working conditions, which take into account the specifics of concrete work in structures (nature of loading, environmental conditions, etc.):

1. γ_{b1} – for concrete and reinforced concrete structures, is introduced with the calculated resistance values of concrete R_b and R_{bt} and takes into account the duration of static load impact;
   a. $\gamma_{b1} = 1.0$ in case of non-permanent (short-term) impact of the load,
   b. $\gamma_{b1} = 0.9$ in the case of continuous (long-term) exposure to the load.

For cellular and porous concretes $\gamma_{b1} = 0.85$. In the case of lightweight concrete, for the R_b resistance value $\gamma_{b1} = 0.85$ (the reduction of the R_{bt} resistance value is regulated by the γ_{b6} factor).

2. γ_{b2} – for concrete structures, is introduced with the values of calculated resistances of concrete R_b and takes into account the nature of decay of similar structures, $\gamma_{b2} = 0.9$.

In accordance with American current building standards "USA" the required anchorage design length of the bar in tension, is determined by the following formula:

$$l_d = \left(\frac{f_y}{1{,}1 \cdot \lambda \cdot \sqrt{f_c'}} \cdot \frac{\psi_t \cdot \psi_e \cdot \psi_s}{\left(\frac{C_b + K_{tr}}{d_b} \right)} \right) \cdot d_b, \tag{7}$$

in which the confinement term $\frac{C_b + K_{tr}}{d_b}$ shall not be taken greater than 2.5, and

$$K_{tr} = \frac{40 \cdot A_{tr}}{s \cdot n}, \tag{8}$$

where:

f_y is a specifed yield strength for nonprestressed reinforcement,

f_c' is a specifed compressive strength of concrete,

d_b is a nominal diameter of bar, wire, or prestressing strand,

A_{tr} is a total cross-sectional area of all transverse reinforcement within spacing that crosses the potential plane of splitting through the reinforcement being developed,

s is a center-to-center spacing of items, such as longitudinal reinforcement, transverse reinforcement, tendons, or anchors,

n is the number of bars or wires being spliced or developed along the plane of splitting. It shall be permitted to use $K_{tr} = 0$ as a design simplification even if transverse reinforcement is present.

The modification factors are shown in Table 1 and Table 2.

In accordance with American current building standards "USA" the required anchorage design length of the bar in compression shall be greater than (9) and (10):

$$l_{dc} \geq \left(\frac{0,24 \cdot f_y \cdot \psi_r}{\lambda \cdot \sqrt{f_c'}} \right) \cdot d_b , \tag{9}$$

$$l_{dc} \geq 0,043 \cdot f_y \cdot \psi_r \cdot d_b . \tag{10}$$

Table 1. Modification factors for tension

Modification factor	Condition	Value of factor
Lightweight λ	Lightweight concrete	0.75
	Normalweight concrete	1.0
Reinforcement Grade ψ_g	Grade 280 or Grade 420	1.0
	Grade 550	1.15
	Grade 690	1.3
Epoxy* ψ_e	Epoxy-coated or zinc and epoxy dual-coated reinforcement with clear cover less than $3d_b$ or clear spacing less than $6d_b$	1.15
	Epoxy-coated or zinc and epoxy dual-coated reinforcement for all other conditions	1.2
	Uncoated or zinc-coated (galvanized) reinforcement	1.0
Size ψ_s	No. 22 and larger bars	1.0
	No. 19 and smaller bars and deformed wires	0.8
Casting Position* ψ_t	More than 300 mm of fresh concrete placed below horizontal reinforcement	1.3
	Other	1.0

*The product $\psi_t\psi_e$ need not exceed 1.7.

Table 2. Modification factors for compression

Modification factor	Condition	Value of factor
Lightweight λ	Lightweight concrete	0.75
	Normalweight concrete	1.0
Confining Reinforcement ψ_r	Reinforcement enclosed within (1), (2), (3), or (4): (1) a spiral (2) a circular continuously wound tie with $d_b \geq 6$mm and pitch 100 mm (3) No. 13 bar spaced ≤ 100 mm on center (4) hoops in accordance with 25.7.4 spaced ≤ 100 mm on center	0.75
	Other	1.0

Results and Discussion

A comparison values of the anchorage lengths was made between different grades of concrete (B20, B25, B30) and diameters (25mm, 28mm, 32mm) considering three foreign building standards. Reinforcement bar class was adopted unchanged, A500C class. Two different cases were considered: in one case, the reinforcement is taken in tension, in the other case, in compression. The calculation results are presented bellow graphically using the "Wolfram Mathematica" software package [9-11] (Fig. 2-5).

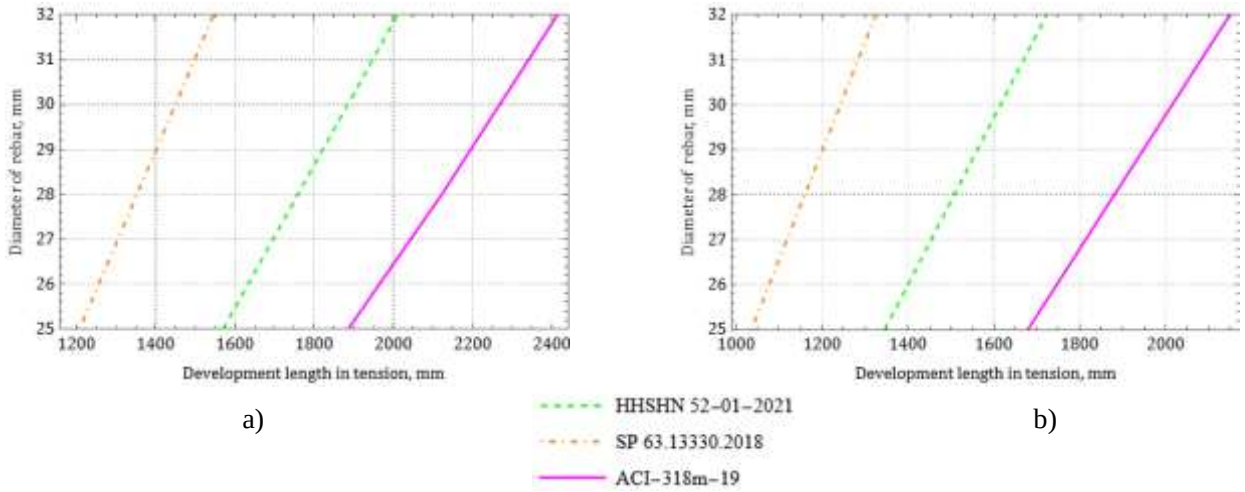

Fig. 2. *Values of anchorage lengths of tension reinforcement in case of concrete class B20 (a) and B25 (b)*

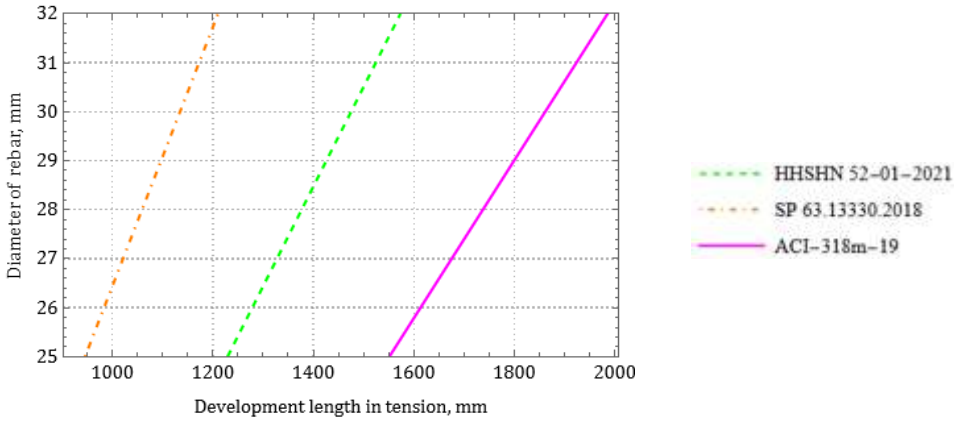

Fig. 3. *Values of anchorage lengths of tension reinforcement in case of concrete class B30*

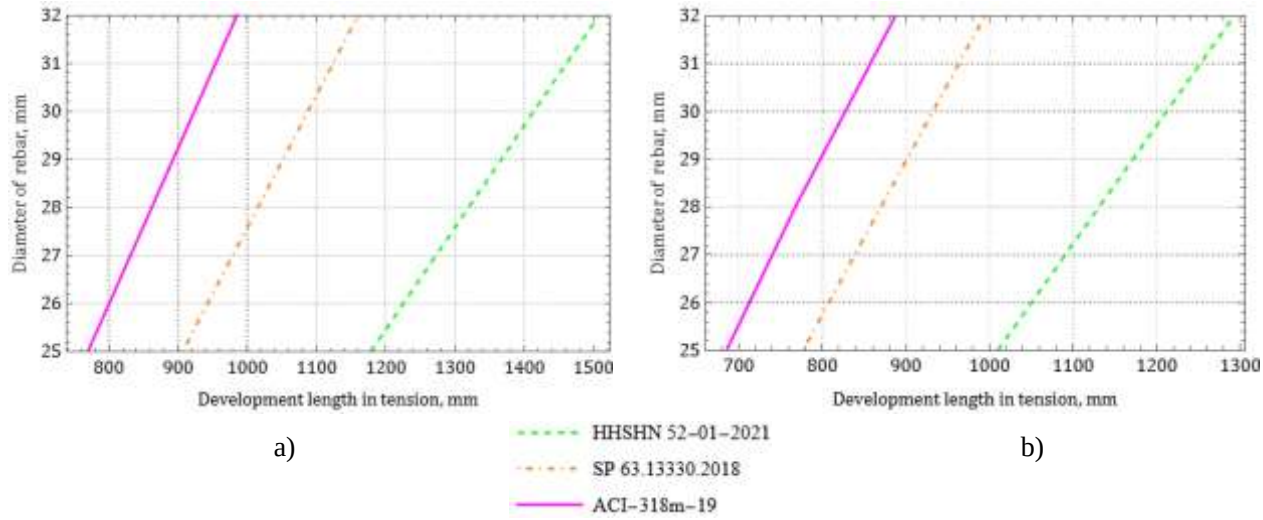

Fig. 4. *Values of anchorage lengths of compression reinforcement in case of concrete class B20 (a) and B25 (b)*

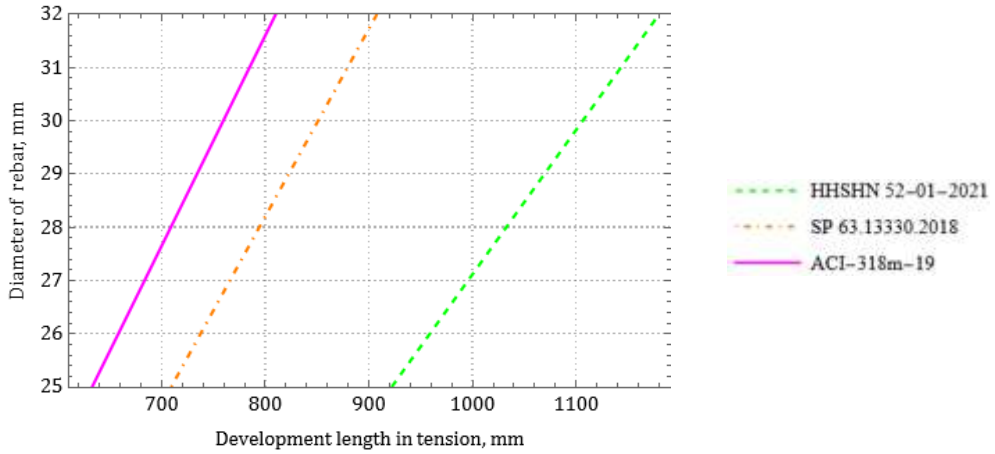

Fig. 5. *Values of anchorage lengths of compression reinforcement in case of concrete class B30*

After analyzing the results of the calculation, it becomes clear that the maximum anchorage length of tension reinforcement is required according to "USA", and in the case of compression reinforcement, it is according to "RA". The results are shown in Table 3.

Table 3. The development length results compare to HHSHN 52-01-21

Codes	Tension			Compression		
	25mm	28mm	32mm	25mm	28mm	32mm
	B20 class concrete					
СП 63.13330.2018	0.769	0.769	0.769	0.769	0.769	0.769
ACI 318-19	1.167	1.171	1.167	0.653	0.653	0.653
	B25 class concrete					
СП 63.13330.2018	0.769	0.769	0.769	0.769	0.769	0.769
ACI 318-19	1.199	1.199	1.199	0.679	0.679	0.687
	B30 class concrete					
СП 63.13330.2018	0.769	0.769	0.769	0.769	0.769	0.769
ACI 318-19	1.208	1.199	1.199	0.687	0.687	0.687

Summing up the results obtained, it can be noted that the anchorage length also should be checked by the American building standards when designing buildings and structures.

Conclusion

Thus, it becomes clear that in the cases of both tension and compression, all concrete classes and rebar diameters, the value of the anchorage length obtained by "RA" is 23.1% more than the one obtained by the "RF". In the case of tension, the value of the anchorage length obtained by "USA" is 16.7-20.8% more than the one obtained by the "RA", and in the case of compression, the value obtained by the "RA" is 31.3-34.7% more than that obtained by "USA" (Fig. 6).

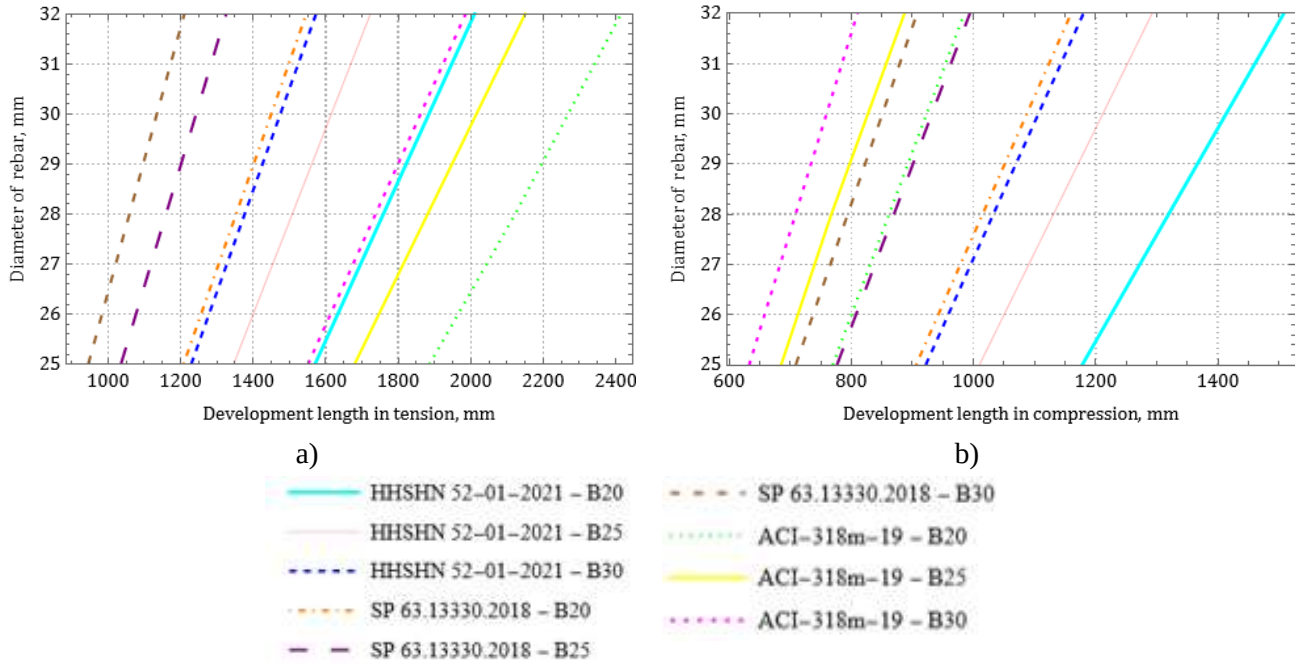

Fig. 6. *Comparison of the values of the anchorage lengths of the tensioned (a) and compressional (b) reinforcement in the case of concrete of class B20, B25 and B30*

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CHALLENGES TO RESIDENTIAL QUARTER RECONSTRUCTION: THE CASE OF THE CENTER OF YEREVAN CITY

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Abstract: *This paper examines the key challenges to the reconstruction of residential development in urban areas. It aims to conduct a comparative analysis of the reconstruction processes of residential quarters in Yerevan and in international practices and to identify certain principles that are appropriate for the further development of the process in Yerevan. The paper presents the features of the reconstruction processes that took place in the sphere of a residential development of the city of Yerevan. The study has been conducted on the reconstruction processes of various nature and content of residential quarters in past decades in a number of cities around the world, focusing on the analysis of topics that remain unexplored in the practice of Yerevan city. A comparative analysis of the findings and conclusions made in the framework of this paper allows us to reveal the strengths and weaknesses in the research and design works for the reconstruction of residential quarters in Yerevan already developed, as well as to develop principles for the choice of study directions, analysis methods, systematization and classification objects, which can be applied to local and international research on the given topic and in the design processes.*

Keywords: *urban structure, residential quarter, development, key challenges, overview, reconstruction, principles, city center, Yerevan.*

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Introduction

The formation of the residential architecture is a complex task that is tied to the various requirements of the time (social conditions, forms of spatial organization, technical capabilities), and reflects a multitude of functional, artistic, social and economic considerations. However, time leaves its trace on the architecture of a city. Cities, as living organisms, change over time, losing some of their properties and acquiring new ones. Residential development also evolves. Social progress occasionally imposes new demands on the residential environment, and household formation is never complete, always requiring new solutions. Consequently, residential development requires constant reconstruction and modernization and the residential architecture is constantly subject to research, analysis and prediction of development prospects.

The present paper focuses on key challenges to the reconstruction of residential quarters in cities, considering the quarters as an inseparable element of the general concept of housing (from apartment to city).

The paper aims to conduct a comparative analysis of the reconstruction processes of residential quarters in Yerevan and in international practices and to identify key principles that are appropriate for the further development of the process in Yerevan. This was the basis for the determination of the objectives discussed in the paper, which were expressed in the elaboration of separate parts arising from the structural sequence of the paper.

The first part presents the peculiarities of the reconstruction processes that took place in the field of residential reconstruction in the city of Yerevan. Those are identified based on a generalization of researches, projects, and proposals made from the 19th to 21st centuries. The material is summarized in a few directions of the research subject, distinguished according to the principle - from general to particular: historical process of development, researches and proposals relating to the reorganization of yard spaces, the

city center and its residential quarters. The first part of the paper builds on the study of Armenian scientific publications (15 publications, 17 authors) and project proposals (7 projects, 8 authors), as well as on the field observations and measurements, surveys, cartographic and archival materials (recovered from Yerevan City Hall, the Agency for the Protection of Historical and Cultural Monuments of the Staff of the Ministry of Culture of the Republic of Armenia, the Yerevan History Museum, the National Museum-Institute of Architecture of the Republic of Armenia).

The second section of the paper studies the multidimensional features that underlie the reconstruction procedure of residential quarters in different cities across the globe. It examines the nature and content of various reconstruction techniques as applied to residential complexes in 15 cities worldwide. The findings of the study are grouped according to several characteristics of the reconstruction process focusing on the topics that remain unexplored in the practice of Yerevan city, namely research approaches and methodology, identification principles of the key challenges, development models of proposals, implementation and management tools. The second section of the paper was developed through the analysis of international scientific publications (26 publications, 49 authors).

The third and final part of the paper tackles the issue of prospects for the reconstruction of residential quarters in the city center of Yerevan. Analysis of past research and design works for the reconstruction of residential quarters in Yerevan reveals the strengths and weaknesses of said research and planning. Their comparison to the international practice of residential reconstruction led to the development of a number of principles for the selection of research paths, their analysis methods, a series of principles regarding the choice of the objects of systematization and classification, which needs to be applied to local and international research on the given topic and in the design processes.

Materials and Methods

The work was carried out on the basis of field studies of individual sites and specific elements of development as well as the study of published and archive sources on international and Armenian architecture. Methods of theoretical research, analysis, synthesis, systematization, classification and generalization of the material were used.

Result and Discussion

Reconstruction in the urban structure of Yerevan: summary of the journey, current situation, implemented studies and proposal

Housing modernization and renewal are the main issues of the housing policies of states. Meanwhile, reconstruction is a major trend of contemporary world architecture and has served as the principal tool for reforming and improving pre-established urban environments [1]. Urban reconstruction is a complex and multifaceted process that should be the result of the joint, complementary work of architects and many other related specialists [2]. This is witnessed through many instances of urban development interventions in cities across the globe (Salvador, Anhui, Wuhu, Tianjin, Hubei, Birmingham, Sheffield, Veszprem, Istanbul, Madrid, Huesca, Voronezh, Aceh, Nias, Lausann). Their experience shows that it is important during the design development not to view the selected area as a separately functioning environment, but pay special attention to its current urban situation, social conditions and architectural and artistic features. Urban development interventions are a recurring phenomenon performed by way of reconstruction projects. The latter are the result of comprehensive processes that incorporate different stages and are conditioned by various circumstances, including population and urban area growth, technogenic and natural disasters, evolving social requirements, negative effect of time, technological advances and other phenomena. Especially alarming,

noteworthy and underestimated are the rates of growing urbanization [3]. According to World Urbanization Prospects (2014), the share of people living in urban areas is larger than of those living in the countryside, with 54% of the world's population now settled in towns and cities. That number is expected to increase to 66% by 2050 [4]. Population growth rates of this scale directly impact the land consumption rate of urban settlements, owing in particular to the constant need to increase housing stock. For instance, this is reflected in the development history of the city of Madrid of the past 15 years, during which its area grew faster than in all the previous centuries combined on account of its ever-increasing suburban housing stock [5].

On the other hand, as Elena Lacilla Larrodé, Harry Smith and José María Ordeig Corsini (2019) explain, quoting Logan, and Firley and Stahl "Throughout history the shape of cities has been strongly influenced by preferences and habits in housing. As a corollary, the relationships between houses, the way they fit together to make neighbourhoods and the way they interrelate with other urban activities have determined the quality of city life" and "Housing is the most significant built form in the urban landscape and its success in achieving a sense of place is one of the bedrocks of social continuity" [6,7,8]. Consequently, the reconstruction of residential areas exerts great influence on the overall perception of a city's image and must be thoroughly studied.

In the above-mentioned context, Yerevan is no exception. Its urban structure and residential areas at different times also did not avoid the multifactorial and multilateral reconstruction processes that are still going on during the period of intensive changes in the city space. We will try to summarize the reconstruction of the elements of residential development in the center of Yerevan within the framework of chronological development.

Historical development

Like many other cities, Yerevan has also gone through multilateral reconstruction processes throughout its history. The establishment of the present-day city of Yerevan began thousands of years ago and has since welcomed many civilizations, held different forms of government, and survived through wars and disasters. And each such phenomenon has left a lasting impact on the historical development of its urban structure. In this context, the chronology of Yerevan's modern urban development dates back to the end of the 17th century, when the city structure underwent a complete transformation after the earthquake of 1679.

Whereas, the first significant processes of reconstruction of the urban structure of Yerevan took place in the 19th century. The formation of the province of Yerevan under the Russian Empire in 1828 led to a drastic change in the worldview, from East to West, which consequently became a basis for embarking on a new era in the history of Eastern Armenian architecture. One of the first expressions of the latter was reflected through the general plans of Yerevan of 1837 and 1856, based on the principle of regular planning of the territory. Here the functional zoning is preserved and at the same time, the main road segments of the street network are regulated (Fig. 1 a,b). Many of them still constitute the current street network in the center of Yerevan. The regulation of the street network leads to a fundamentally different composition-scale approach to the organization of the living environment, the creation of perimeter quarters with yard areas. Studies show that this leads to: improving the forms and functional organization of the housing unit; establishing a closed, private inner-yard space, which promotes the perception of these spaces as cells of social communication; regulating functional processes and adapting to the climatic conditions of the place [9, 10].

The following phase of reconstruction of the city structure is directly associated with Armenia becoming a member of the USSR. The rapid industrial development of the 1920s caused a sharp increase in the population of Yerevan, which evoked issues related to regular development and organization of life, thus triggering the need for reconstruction. In 1923-24, architect A. Tamanyan developed the new general plan for Yerevan based

on the principle of partial preservation of the existing system, combined with the approach of radical reconstruction (Fig. 1c). This has led to the formation of the current perimeter development of the center, which is manifested in the enlargement of yard areas and the gradual weakening of the private status of yards. Thus, the small provincial settlement of the past was restructured into a completely new-scale urban area. It is this reconstruction plan that defines the modern features of the center of Yerevan and makes it recognizable among other cities [11].

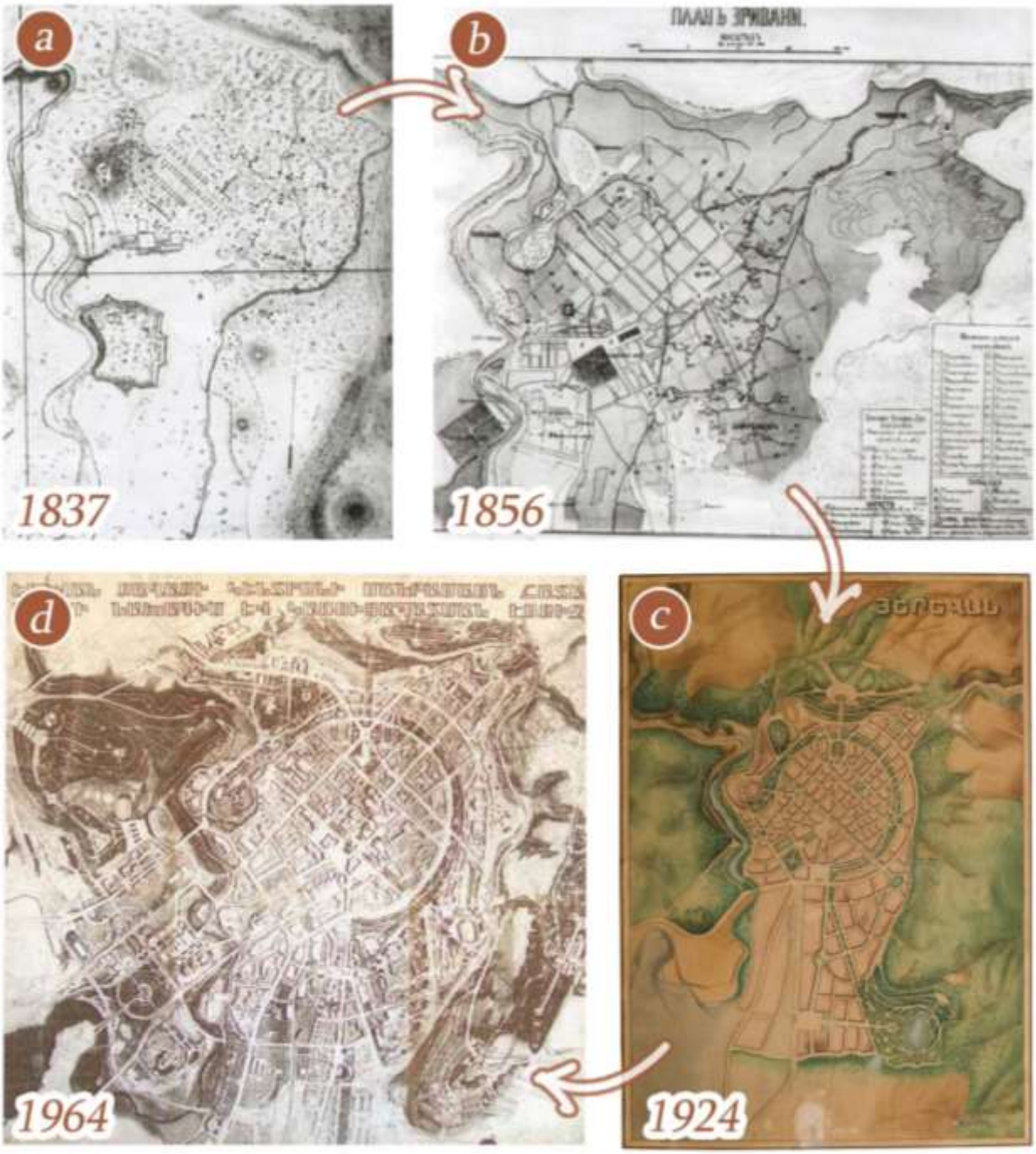

Fig. 1. *Development of the city structure of Yerevan (general plans through the history)*

From the 1950s, the city underwent territorial expansion through the integration of neighboring settlements, which consequently led to the disruption of the functional processes of the city, and thus, caused significant deviations from the revised general plan of 1951. From the end of the 50s, the urban development of residential structures evolved in two directions. Mass residential construction developed in the peripheral areas of the

city, carried out on the principles of free or line building of quarters, with a structure that strongly differed from the traditional perimeter development of the yard areas. Whereas, the center continued to adopt its traditional perimeter development model. However, yard areas underwent a significant change in their functional conception, since they lost their privacy and gradually evolved to public multi-use service areas. As a result of these complex processes, the concept of unity embraced in the urban development of the city gradually disappeared. The city, formerly intended to be an independent and separate functioning and developing organism, quickly evolves into a center of a large city. From this period on, issues of urban structure development were distinguished. The problem of the city center reconstruction within this context became a separate matter [10].

In order to avoid irregularities in the development plan of the city, a general plan for the reconstruction of the center was outlined in 1964, which later composed the basis for the general plan of the city in 1971 (Fig. 1d). According to it, the construction of high-rise residential buildings in the center of Yerevan commenced. In the 1970s and 1980s, the integration of many standard and amorphous high-rise residential buildings into the perimeter development of the center, including separate, local public structures (garages, ancillary buildings, engineering, storage, buildings and outbuildings), contradicted the functional-spatial structure of the environment which underwent certain formation process. Hence, this period initiates the process of demolition of the yard areas of the city center. The traditional yard environment undergoes radical changes. Social space of the yard loaded with green, water and recreation zones decreases, thereby becoming full of construction disrupting its functional organization. This approach to reconstruction, primarily aimed at supplying for the city's housing shortage, leaves an irreversible tollon the structure of the center, which inevitably brings to distortion of the scale and image of the historic core [12].

It should be noted, that since the 1920s, the new perimeter system of urban development is implemented in the existing development zones. Hence, a full demolition of the old housing stock was provided. However, due to the lack of economic means, accompanied by the need to increase the housing stock, only areas designed for new buildings are demolished, which are located on the perimeter zones of the quarters. The fact that more attention was paid to the artistic side of street architecture in the 1930s and 50s, is also important, as a result of which the organization of inner-yard areas becomes less significant. So the demolition of old houses located in inner-quarter zones, which was necessary for the organization and development of the yard space, was constantly delayed throughout the whole Soviet era.

The next and last period of reconstruction of the city center was during the post-Soviet years. It should be noted that if past processes of city reconstruction, in spite of results, had a certain direction, as of the 1990s, its development became entirely spontaneous. The unfavorable political and socio-economic situation of the country (caused by the formation of a new economic structure; the war; and other factors) leads to uncontrollable urban developments. In the perimeter structure quarters of the center within the above-mentioned not demolished zones of old housing, one by one, high-rise buildings are constructed, with each rising above the other, in a completely disordered manner, without unity of urban planning, alien to the scale of the city and based on purely economic motives. The issues of urban integrity are completely ignored throughout the process of reorganization in even the most comprehensive sections in the Northern and Main avenues of the city, which represent the compositional axes of the center. This tendency to pursue purely profit-oriented activities has significantly damaged the historical and cultural values of the city, and distorted its overall unique composition integrity. In the mentioned processes, in practice, the demands and opinions of the population are not taken into account, which causes contradictory responses among the public. Moreover, it also provokes serious problems of security and sanitation within the quarters [13,14,15]. The evolution ot the construction of the central quarters of Yerevan is illustrated in Fig. 2.

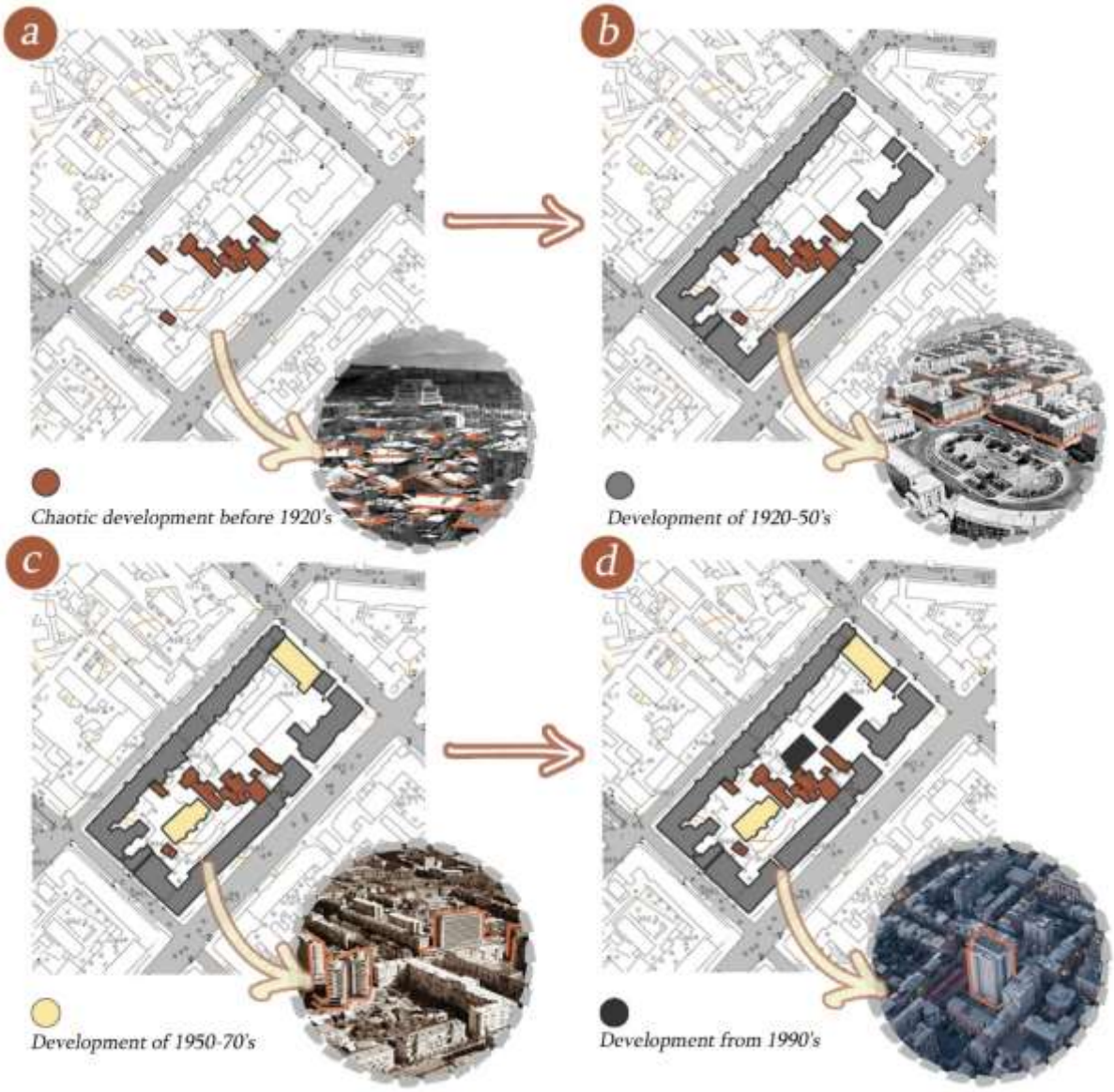

Fig. 2. *The evolution of the development of central quarters of Yerevan in different periods of the last century*

Mentioned different circumstances lead to the fact that the studies of the problem of reconstruction of the constituent elements of the city structure of Yerevan have become topical in the field of Armenian architectural science since the 2000s.

Summary of researches and proposals for the reorganization of yard spaces of Yerevan

The summary of the works related to the issues of yard spaces in the residential areas of Yerevan developed by the NUACA (National University of Architecture and Construction of Armenia) during the last decades allows to make an analytical generalization of their results, which is reflected in the provisions presented below.

Within the structure of the city of Yerevan, the yard space can be described as:

- the basic element of the urban structure, which largely determines the architectural image and historical identity of the development,
- an important component of urban improvement,

- the transitional degree from the intimate space of an apartment to larger urban areas: the preservation of this gradation in the hierarchy of the urban organism is an important factor in ensuring a psychologically healthy and full-fledged living environment [16].

The process of organizing the yard space in the structure of the city of Yerevan throughout the last century can be classifised into the following main chronological stages of development (Fig. 3):

- establishment of a yard in the center of a private house or an apartment building (stable social unit of a residential area - a traditional patio within the linear and perimeter development) (Fig. 3a),
- establishment of a yard in the center of the space enclosed by apartment buildings (reorganization of the yard in a new scale of perimeter development) (Fig. 3b),
- establishment of the yard in the open spaces between freely installed buildings (redefinition of the idea of the yard within the general spaces of free development) (Fig. 3c),
- establishment of the yard in the space enclosed by residential buildings structured in groups (reunification of the yard under the new conditions of the grouped development regulated space) (Fig. 3d),
- loss of the yard in the area filled with irregularly placed buildings (destruction of the yard in the conditions of widespread spontaneous development of the inner-areas of a quarter) (Fig. 3e).

A survey was conducted to determine the current requirements for reorganizing the yard areas, which sought to understand the needs of residents with respect to yards, their importance, and the structural solutions they provide. Based on the analysis of the answers provided by 200 residents, the overall issues raised by the latter can be categorized as follows:

- the relevance of the impact of yard spaces on human life,
- the importance of the social component within the formation of the architectural and spatial solutions in yard spaces,
- the communal necessity of yard spaces as a recreational and interactive environment in quarters,
- the significance of green spaces and playgrounds provided by yard spaces,
- the scarcity of recreational areas conditioned by unorganized parking areas, continuous construction processes, and the gradual reduction of green spaces [8,16,17,18].

The analysis of the results of the field observations and the surveys allows to identify the main negative aspects associated with the evolution of yard spaces in the city:

- unjustified densification: violation of the functional and compositional balance of the yards of the perimeter development due to the construction of multi-story residential buildings within the quarters (city center),
- installation of garages, private business structures and various ancillary buildings (center and suburbs),
- absence of a clear and organized layout between passages and recreation zones.

The elaboration of the typological classification of the yard areas, which was executed based on their functional layout characteristics (area, outline, green area, playgrounds, sports grounds, parking lots, passages and approaches) and on their location in the city structure, allowed to develop several proposals for their reorganization. These proposals were presented in the form of scientifically substantiated recommendations, which are based on the differentiated approach to the spatial layout, the outline and the absolute dimensions of the yards. The analytical summary of the results of the proposals and the mentioned classification are further explored in Fig. 4 [17].

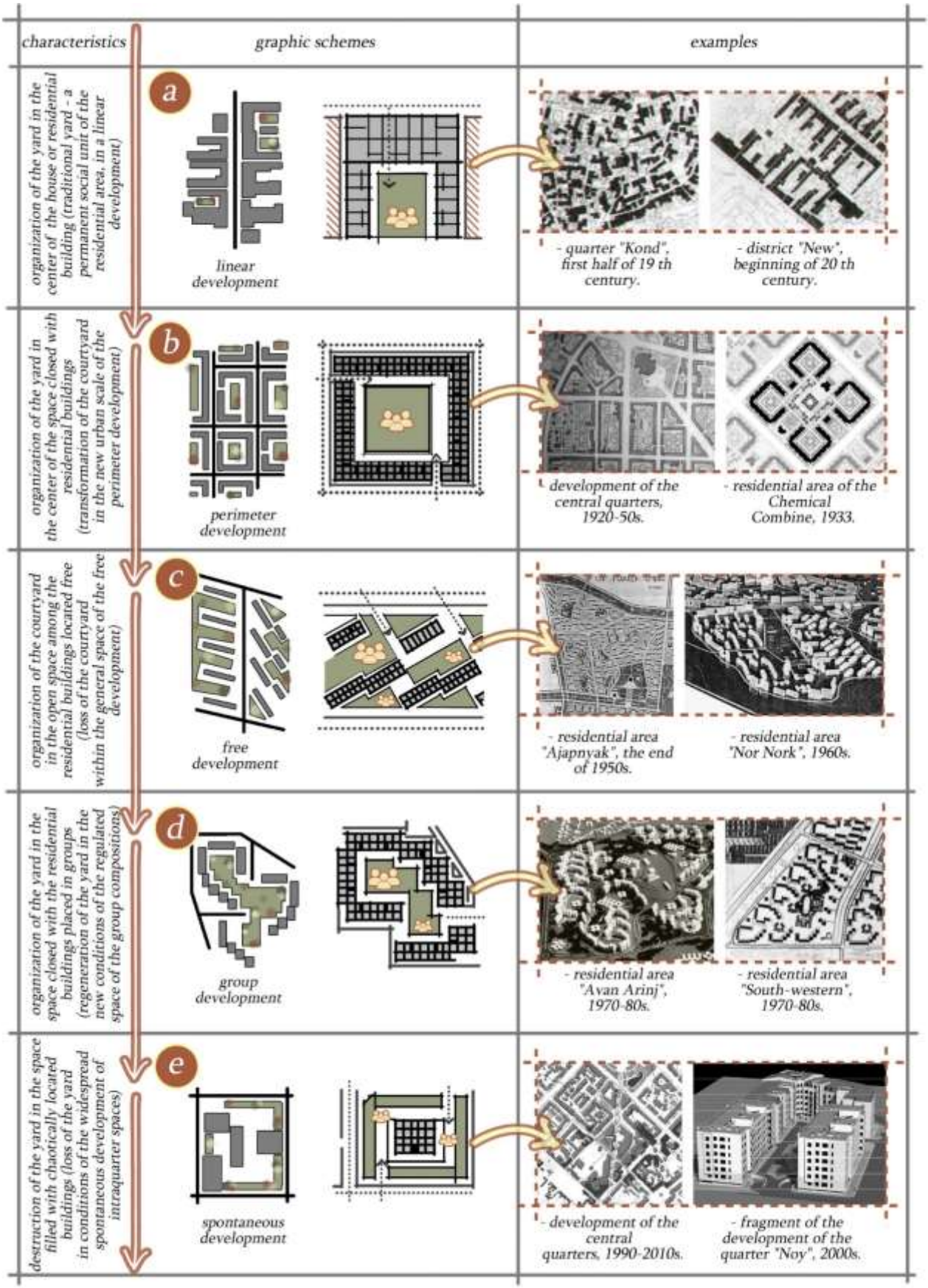

Fig. 3. *Main stages of the yard space development in Yerevan city*

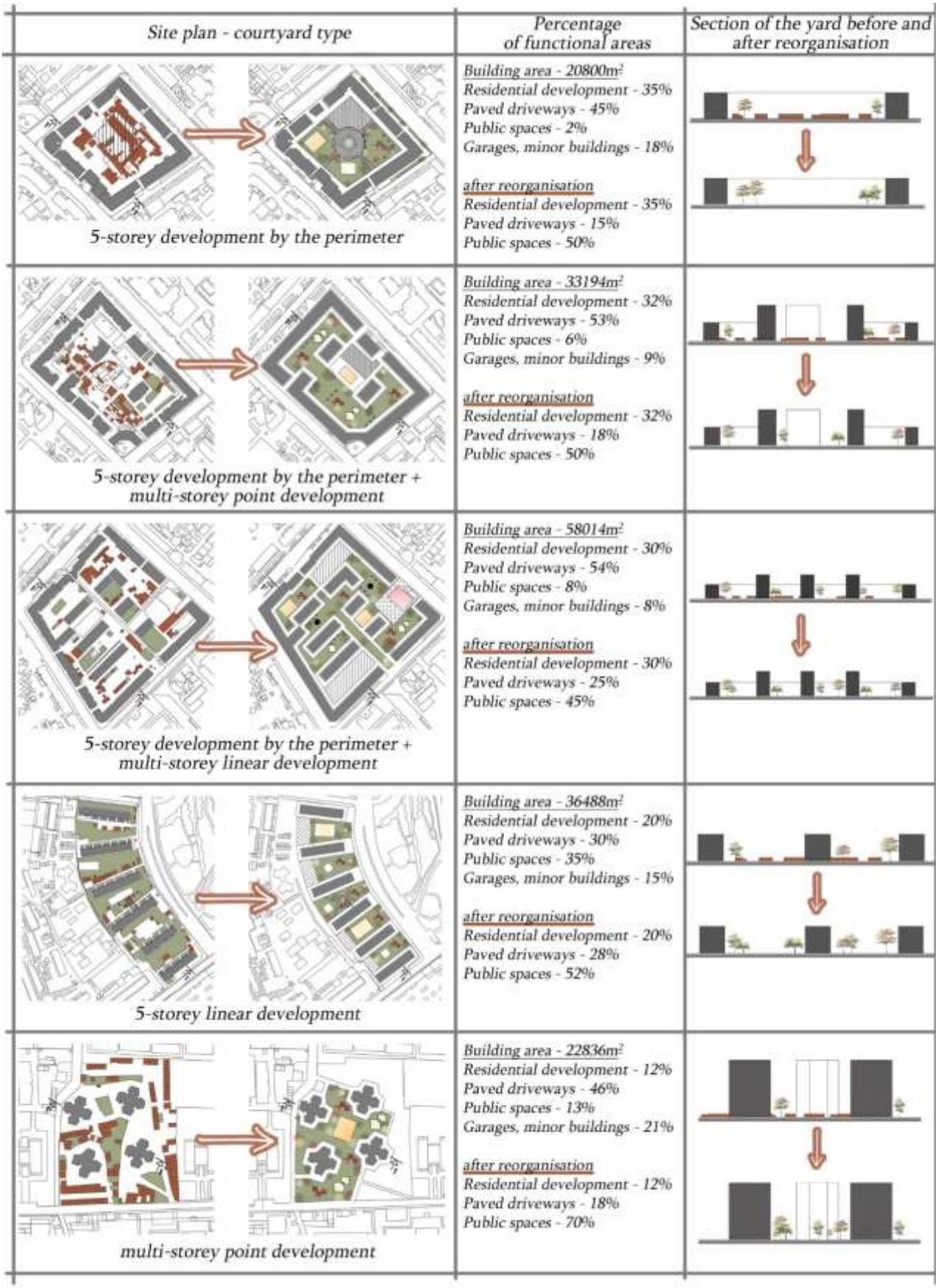

Fig. 4. *Classification of courtyard spaces of the city of Yerevan and proposals for their reorganization*

The city center

A number of studies conducted at the NUACA in recent years include also project proposals for the reconstruction of certain quarters in the center of Yerevan, which refer to the following parts of the center:

- quarter enclosed by Hanrapetutyan, Tpagrichner and Vardanants streets (2010, authors: R. Azatyan, K. Azatyan, Fig. 5a),
- quarter enclosed by Vardanants, Kochar, Kajaznuni and Vratsyan streets (2018, author: K. Azatyan, Fig. 5b) [19],
- quarter enclosed by Nar-Dos, Tigran Mets, Zavaryan and Khorenatsi streets (2019, authors: A. Ohanyan, K. Azatyan, Fig. 5c) [20],
- quarter enclosed by Charents, Vardanants and Shahinyan streets (2020, authors: I. Mirzoyan, K. Azatyan, Fig. 5d) [21],
- quarter enclosed by Kochar, Tigran Mets and Kori streets (2020, authors: A. Ohanyan, A. Gurgenyan, Fig. 5e),
- quarter enclosed by Khanjyan, Tigran Mets, Byuzand and Hanrapetutyan streets (2020, authors: A. Mirzoyan, A. Gurgenyan, Fig. 5f),
- quarter enclosed by Arshakunyats, Kristapor and Sevan streets (2020, authors: M. Aydinyan, A. Engoyan, Fig. 5g) [22].

Observational analysis of the mentioned researches and development projects shows that those were aimed to solve the accumulated problems within various quarters by providing sustainable solutions ensuring a prosperous living environment. Different means were deployed to achieve the given objective. In order to establish a more regulated environment, it is necessary to demolish the various constructions along the streets and in the yards. In some cases, the establishment of new structures are planned to compensate the owners of demolished properties, meanwhile promoting economic activity within quarters. On the lower floors of new residential buildings, public spaces are provided to promote servicing, renting or selling activities to provide for the basic needs of the quarter. Taking into account the high value on the real estate market, respective large public structures are proposed in certain quarters, depending on the location of quarters. In case of large industrial structures in the quarters, options of their renovation are considered, with the feasibility of offering further functions for public and residential usage. In addition, considering the growing number of cars, along with the overall scarcity of parking spaces, the proposals also include underground parking lots, the volume of which is calculated in accordance with the demand of quarter on the whole. In some cases, the proposal envisages the usage of attics in existing buildings, in order to improve the existing roof constructions in poor condition and also to expand possible areas of sales within the quarter [22, 24].

The proposed design concepts are aimed at ensuring the self-sustainability of the project on account of the generated real estate, meanwhile prioritizing the benefits of the public instead of business interests. The main goal of the projects is to improve the urban environment. Although the projects are not intended to provide additional financial income, the economic aspect of the issue has not been disregarded as well, in order to attract the attention of investors and governing bodies. Therefore, additional development is considered in a measure, derivable financial resources of which will be sufficient for the process of solving the problems of the quarter (design and research works, demolition, construction, improvement). Moreover, the main financial sources for the reorganization of yard spaces are considered:

- measures taken at the municipal level (municipality, district administration, community),
- private investments.

The financial calculations in the proposals were made with the following considerations:

- all project implementation costs are covered at the expense of the generated real estate (the positive difference between income and expenses is 15.66-26.67%),
- compensation for the demolished objects is envisaged at the expense of new development,
- research, design, construction and installation costs and real estate prices are determined according to the official normative and statistical data of the Republic of Armenia.

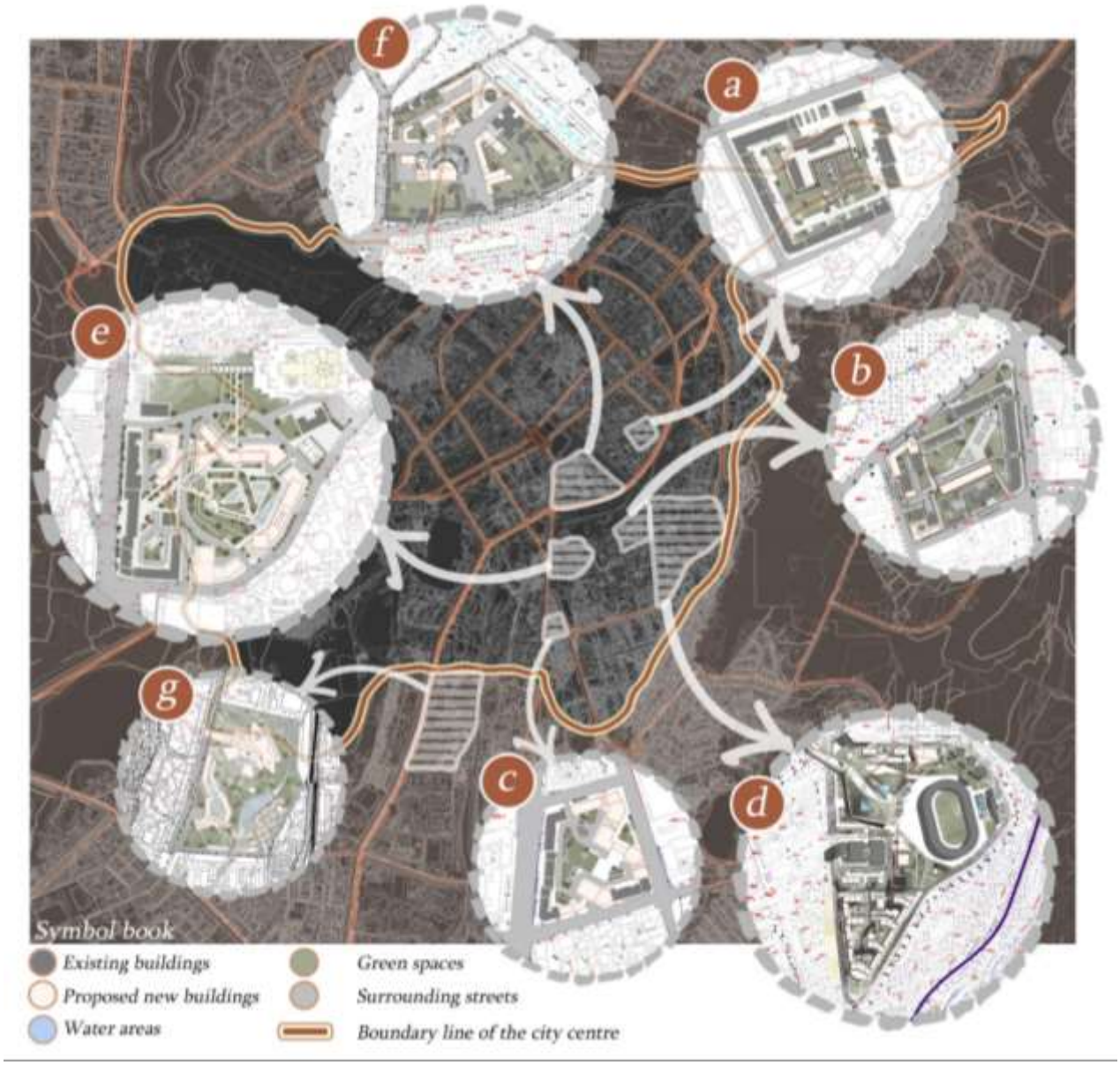

Fig. 5. *Proposals for the reconstruction of some quarters of the center of Yerevan*

Residential quarters of the city center

The project-proposals discussed include a significant amount of research into the center's residential quarters. Examination and comparison of those allow us to highlight certain patterns, which become apparent in the formed situation.

The summary of the various proposals shows that the features characteristic to the structure of the quarters identified in the research findings, depend on the peculiarities of the quarter placement in the structure of the center and conditioned by presence and quantity balance of the following components:

- ordinary structures or structures of cultural value,
- ramshackle housing stock,
- garages,
- structures implemented in violation of the urban planning requirements,
- green areas.

Given the aforementioned, for the reconstruction process plan the residential quarters of the center of Yerevan can be classified according to:

- the position and significance within the structure of the city center,
- the amount of development subject to demolition,
- the percentage of the development along the perimeter,
- the feasibility of new construction,
- the presence of historically or culturally significant structures.

The problems, emerged in the quarters, can be classified into the following groups:

- urban planning (violations of development density, distance between buildings, safety zones, pedestrian and transport routes, and provision of approaches, as well as significant volume of dilapidated, irregularly constructed private houses, garages, service structures in the yards, and spontaneously constructed development along the streets on the outside of the perimeter of the districts),
- structural (non-compliance with the current normative structural requirements from a significant part of the buildings, existence of a considerable number of impermissible interventions in the load-bearing structures, poor condition of the roofs),
- functional (severe lack of recreation areas, green zones, playgrounds, sports squares, pavilions, improvement elements, parking lots and landscaping, as well as the negative impact on the living conditions of residents, caused by public caterings, service and trade facilities located on the lower floors of residential buildings),
- economic (low power-efficient level of existing buildings),
- artistic (extremely low levels of development composition solutions, architectural appearance of buildings and aesthetics of the environment).

In the projects discussed:

1. the dynamics of changes in the main technical characteristics can be summarized through the following indicators:
   - built-up area: reduction of 4.7 - 35.8%,
   - the total surface area of residential buildings: from a reduction of 35.2% to a growth of 35.9%,
   - the total surface area of public buildings: growth of 12.8 - 211.7%,
   - coefficient of green zones: growth of 13.0 - 265.2%,
   - coefficient of population density: from a reduction of 26.3% to a growth of 66.4%.
2. the comparison of the main economic indicators leads to the following limits:
   - value of research, design, construction and installation works: within 1.20 - 32.24 bn. AMD,
   - the value of formed real estate: within 1.52 - 37.29 bn. AMD,
   - the duration of the process: between 20 and 40 months.

The positive aspects of the results obtained in the project proposals can be highlighted as:

- reduction of the built-up area, increase of the parking and green areas, dismantling of dilapidated structures along the streets and in the inner-quarter area, in violation of urban planning requirements, as well as organization of a well-maintained yard space, regulation of street development and improvement, provision of safe living conditions in the quarter.

The negative aspects can be highlighted as:

- the housing stock and population within the same spatial boundaries, the tendency of an increased total area of buildings.

Overview of the international practice of reconstructing residential quarters

Summarizing the experience of reconstruction of residential quarters of the center of Yerevan allows us to highlight the issues that have received attention in research papers and project proposals developed on their basis. These are the following: historical features of the reconstruction of the urban structure, the formation of a modern center and the growth of perimeter development, determination of the status of the yard space and classification of chronological stages of its organization, typological classification of the quarters, identification of characteristic features of their structure, determination of dynamics of technical and economic characteristics, coordination of the identified issues. At the same time, such generalization and parallels drawn with international practice make it possible to identify those main areas, generally unexplored in local practice. In particular, the methodology and approaches of the research, the role of social and economic factors, the identification of the key challenges characteristic to a particular environment and locality, the choice of recommendations and principles for the formation of proposals, their implementation, and management tools deserve attention and need to be specified. Therefore, specification in the above-mentioned areas of international practice research will be valuable for clarifying the ways and principles of further reconstruction of residential quarters of the center of Yerevan.

Reconstruction projects research approaches and methodology

Similar to any urban development activity, the reconstruction begins with an in-depth and detailed study of the site. This includes the study of historical sources, and graphic and archival materials, social surveys and interviews, field observations, analysis of the obtained material, documentation, the compilation of tables, diagrams and databases based on collected data, and various other research methods. Such approach allows to identify the existing problems in the considered site, and contributes to the development of a more guided and targeted design.

One such comprehensive study was conducted in the Hubei Ancient Village of Luohu District, Shenzhen, Guangdong Province, China. Considered a township under the country's official system of administrative divisions, Hubei Ancient Village, like many other localities in China, began as a historical village that was later incorporated into the nearest developing city, in this case Shenzhen, as a subdistrict of the latter. In conceptualizing the reconstruction of such settlements as Hubei, the following aspects have been thoroughly studied: the history of the village formation, the structure of street networks, historic buildings and their significance under different historical periods, as well as the chronological order of construction of these buildings and their unique architectural features. Their findings presented a basis for the fixing of the architectural preservation of each building, as well as for the creation and analysis of a map detailing their location [25]. All that data was then brought together to develop assessment strategies for maintaining the operation of selected structures in the given quarter (local renovation, major reconstruction, demolition). The degree of thoroughness of the work presents a solid basis for the effective reconstruction and preservation of similar settlements, especially as regards the prioritization of tasks.

Preserved historical urban plans played a particularly decisive role in the reconstruction of another city of Wuhu in Anhui Province, China. Prior to its reconstruction, the city's traditional houses and several of its temples, both of which were built before the 20th century according to the postulates of typical Chinese folk architecture, were preserved under poor conditions. And although such structures occupied only 15% of the city's total area, its historic street networks had not only been preserved, but were also still operational [26]. This and the archival cartographic materials discovered during research that showed the original structure of the city center allowed to restore the past idea behind the spatial development of the city.

Another noteworthy example in terms of the methodology used during the research phase is the reconstruction of the Sarı Kıs¸la barracks building in Istanbul, Turkey. The study of the reconstruction process of the building was carried out in two stages. The first involved identifying the architectural and constructive features of the building, and examining the process of its construction using historical documents and old photos. A study of the other buildings of the same author, and of the construction materials and technologies used during that same period was also conducted. During the next stage in the study of the reconstruction of the building ground-penetrating radar (GPR) surveys and electromagnetic field measurements were implemented to determine the presence of archeological remains in the subsurface of the building site [27]. A comprehensive reconstruction project for the building was proposed on the basis of the findings of the two stages.

Also noteworthy from the point of view of other approaches used in the study phase is the research on the possibilities of reconstruction of residential areas of Chinese cities, the concepts given along the way and the problems of their design and implementation [28]. Here too the reconstruction process requires a study of the origins of a chosen quarter, but with the added requirement that it must also examine the social relations formed between and the real needs of the residents of the quarter.

A similar approach is evidenced in the study of the 2 de Julho neighbourhood in the Brazilian city of Salvador. According to the authors of the study, every citizen has rights to his or her residential environment, both in terms of their free access to the areas and services offered by the city, and their participation in its formation. The 2 de Julho neighbourhood is situated in the historic center of the city, and is surrounded by tourist attractions (part of the neighbourhood is included in the UNESCO World Heritage List) despite housing mainly low-income residents. This has earned the attention of the Brazilian government and investors, who have sought to transform the area by evacuating low-income residents, increasing land prices to attract higher-income residents, and implementing investment projects that involve purchasing property from the original residents of the neighbourhood. In response to such actions, and in anticipation of a change in the position of the authorities, an attempt was made to transfer control of the neighbourhood to the population. The research group 'Lugar Comum' (Common Place) from the Faculty of Architecture of the Federal University of Bahia (FA-UFBA) with neighbourhood residents implemented a project, within the framework of which a group of proposals for the improvement of the neighbourhood was formed. A total of 174 residents took part in the program over the course of 3 years. During the planning several problems were identified that arise in such processes. But it is possible to find their solution based on the experience gained through time. A major obstacle was mobilizing residents, conditioned by their inability to sustain dialogue, the unwillingness of some to engage in public debates, a general distrust towards the proposed projects (due to repeated failure to implement them), as well as display of leadership attitude from some people, lack of competence and professional knowledge in the field [29]. Despite these setbacks, the experiment led to the development of design proposals that are expected to have a positive impact on the reconstruction of the district and will prevent further conflicts between authorities and inhabitants.

An interesting approach is also shown in another work, which presents the results of the joint work of residents and the architects of the architectural department of the Federal Polytechnic School of Lausanne, Switzerland. It emphasizes that the residents are an invaluable source of information and that the existing

potential should be utilized as much as possible. Here, residents also took part in the entire designing process and in order to establish a direct connection with them and for easier perception of the future project, real-size space simulators were used. As a result of such a dialogue between the designer and the future resident, residential houses have been built in accordance with the user's requirements. These houses were constantly monitored during the year following the check-in, revealing the omissions. Such post-project consistent observations can play an important role in the process improvement, preventing authors from repeating the same omissions in the future [30].

Another example of resident involvement in the reconstruction process of a city quarter is that of the Birmingham Jewellery Quarter in the United Kingdom. In order to make the reconstruction more acceptable to its residents, the authors studied their perceptions about the identity of the urban environment in which they resided. Representatives of 13 companies operating in the area took part in the survey, which viewed two architectural structures in the quarter – the former Smith & Peppers factory, which now is the Museum of the Jewellery Quarter, and The "Big Peg" and its surroundings. The "Big Peg" is a multi-story building housing jewelry workshops whose modernist architecture is distinct from the historical architecture of the remainder of the quarter. Respondent opinions on the selected structures varied substantially. While some spoke in favor of the authenticity of the Smith & Peppers factory building, believing it to have largely preserved its historical architecture, others questioned it, claiming the building had in fact lost some of its authenticity after it underwent changes. As for The "Big Peg", many of the respondents viewed the modernist complex as unattractive and out of the city context, while others disagreed that it seemed artificial, explaining that it does not try to replicate the surrounding architecture [31]. Incorporation of various opinions and identification of general provisions allows to formulate a more clear idea about the approach most acceptable to the residents, which in turn has a direct impact on the redesigning process.

Such studies may also be carried out without direct resident participation. One such study was conducted for the reconstruction project of the Five Avenues Historic district in Tianjin, China. A total of 2.923 comments were collected from social media users, which were then classified into categories of positive (2.677), neutral (163) and negative (83) comments. Analysis showed that its residents had a much more positive view of the historic quarter than the tourists who visited it, owing to the collective memory and emotional attachment of the latter to the area [32]. Ultimately, the thorough study based on the comments allowed to shine a light on some of the major complaints of the quarter residents and to find the main directions for improvement.

A study by methodology discussed was conducted in Sheffield, England between 2010 and 2015 on the basis of 3 main approaches:

1. a detailed study of existing documents, including the city center general plans of the years 2000, 2008, and 2013,
2. interviews with City Council officials, consultants, as well as stakeholders in urban reconstruction and participants of the general plan development projects,
3. direct observations of changes in the urban structure, and the use of newly created and redefined public spaces by means of regular visits to the mentioned sites, which also included conversations with citizens [33].

Identifying the key challenges

All of the methods discussed above aim to identify the challenges faced by the quarters considered by each study. Every city, every quarter confronts a unique set of problems depending on their historical development, the changes they have undergone through time, the lifestyles of their residents, and other factors. Their detection allows architects to develop more effective and viable reconstruction projects. For example, the application of the active citizen participation method in the 2 de Julho neighbourhood in Brazil revealed which issues most concerned its residents. These included the lack of public protection in the quarter and the high crime rate that stemmed from it, the problems with its infrastructure, namely the poor condition of its sewer

lines, which leads to the spread of infectious diseases, the absence of green zones, and the disregard of the city authorities towards trees [29].

Another study, this time of the Hubei Ancient Village in Shenzhen, China, revealed that a key challenge for the site was the technical safety of its 560 old houses preserved, half of which were deemed unsafe, with 53 rated grade D dilapidated. The village also lacked public spaces, its historic street network was ill-equipped for modern pedestrian and traffic flows, and its residential spaces were deemed too small, the changes in layout made by residents had ridden certain rooms of lighting, power lines disrupted, garbage collection and street maintenance hampered [25].

Another noteworthy factor is the climate of the area and its direct influence on the design and reconstruction processes. A comprehensive study and perception of the local climate forms recommendations that should serve as a basis for architects and technical specialists [34]. Over time, local authors are already aware of the climatic conditions of the area, taking into account the existing conditions and the influencing factors in their projects. This leads to the formation of an architectural image inherent in the area. In this regard Charles Correa draws interesting parallels, stating that while in North America the primary image of an educational structure is the small red building, in India and some Asian countries, it is a guru sitting under a tree [35]. At the same time, it is very important to keep up with novelties and find new methods for more effective study of climatic conditions, since their clear awareness will lead to the most effective and comprehensive solutions from the authors in their future projects [36].

One of the most common challenges in the reconstruction process is the preservation of urban heritage. The general design principles should be based on local memory and the history of the observed region. In this age of globalization and technical development, such an approach will allow to create a more humane and acceptable environment [37,38]. To gain insight into the problem, Tianhang Liu, Richard J. Butler and Chunyan Zhang studied the 2011 UNESCO Recommendation on the Historic Urban Landscape (HUL), which details approaches to city protection. It touches upon how to overcome new challenges, which the urban heritage faces in the modern world. The paper also emphasizes the differences in the standards of perception and valuation of heritage sites within professional circles and in society at large. It explains that every citizen has their own perception of a given historical structure, which is conditioned by their own aesthetic, emotional, and cultural experiences, and which render the task of outlining common solutions to the reconstruction process all the more complicated [32].

Another common challenge of the reconstruction process is that relating to the city general plan, especially as regards its street network [5,25,28,33]. In their study of the city of Madrid, co-authors explain that cars have become a dominant feature of contemporary cities. As a result, many cities have lost their traditional urban shape and look like continuous passages for automobiles. Today, in many respects, the economic aspect and infrastructures are the priorities. A new approach is therefore needed to reduce dependency on investments and transportation, and shift attention towards ensuring a healthier pedestrian environment [5].

Recommendations and principles

The identification of challenges evidenced by the studies discussed above makes possible the formulation of principles of reconstruction suited to the quarter being considered, which in turn provide the basis for reconstruction project proposals. At the same time, various factors specific to a particular case are taken into account, as it is impossible to be guided by unambiguous and unchangeable design criteria, and even the lifestyle of future residents has a direct impact on the development of design recommendations and the correct guidance of the overall process [39]. In the case of the 2 de Julho neighbourhood discussed above, for example, the three-year joint research project led by its residents and the university group resulted in 43 project proposals grouped around 10 different topics [29].

A different study about the Hubei Ancient Village in China considered the significance of established social relations and determined that the preservation and reconstruction of the historical environment is a dynamic

process that must consider the landscape and the existing social relations on the whole. As such, the study suggests that the reconstruction and preservation of historical urban objects must be carried out gradually to maintain comfortable living conditions for its residents, and prevent social dissatisfaction with the process [25].

The importance of strong social relations is also emphasized in a study of the Indonesian cities of Aceh and Nias, where the reconstruction serves not only to create a more competent residential environment but also to establish higher standards of living and healthier relations among its residents. The study perceives the reconstruction of residential quarters as the main driving force for social rehabilitation and improved urban socioeconomic conditions [40].

There are alternative approaches to proposals for the reconstruction of urban quarters when relevant concepts are presented based not on the problems of a particular quarter, but rather on the classification of quarters. For example, in a study on the reconstruction of urban quarters in China, the authors present different types of proposals for their modernization, such as: 1. perimeter commercial blocks with minimal limits to entry; 2. bounded superblocks without gates; and 3. completely bounded and gated superblocks. However, the same authors simultaneously question the effectiveness of such an approach, considering the specificities of each quarter and the needs of respective inhabitants [28].

While developing proposals for quarter reconstruction, many criteria related to modern needs of life and new urban planning solutions must be taken into consideration. One such criteria, as an example, concerns the availability of green and common areas. For instance, all the apartments in the quarter of Padre Querbes in the Spanish city of Huesca include open spaces in the form of gardens on the ground floor of the building and balconies overlooking the adjacent park on higher floors. Thus, the communal concept of the latter protects its residents from traffic accidents and crime, meanwhile providing them a common space for rest and collective activities. Furthermore, it is imperative to ensure the availability of public facilities within the quarter, therefore, some parts of the ground floors of the project under consideration are non-residential. One of the most important requirements is the type of housing, as well as the population and development density. In this project, for example, the offered housing stock abides by the needs of single-family housing. It is also important to consider urban scale challenges. The new residential buildings presented in the proposal are designed in consideration of the proportions of the existing adjacent construction. The latter encompasses 270 apartments with different designs and layout solutions, which allows for the accommodation of families of different sizes and social interaction between different age groups. This should also be included in the requirements of quarter development [6].

In addition to being necessary, these requirements can also be a useful tool for the designer. For example, between 2008 and 2014, during the reconstruction of one of the central quarters of the Hungarian city of Veszprém, the perception of the urban environment and its aesthetic qualities were completely changed through the improvement of green areas and the incorporation of an active public space. The contrast created by the new materials used and the small architectural shapes gave the existing structures a new lease of life[1].

Implementation and management tools

Reconstruction projects concerned in this section do not pursue any business goals since the authors focus solely on improving urban environments and the lives of their inhabitants that will lead to the formation of a healthier and happier society [41]. As a result, most of the projects need additional funding and the intervention of respective public institutions. For example, almost half (48%) of proposals for the reconstruction of the 2 de Julho neighbourhood in Brazil were intended for government implementation, and in 22% of requests the

[1] D. Holmes, The Reconstruction of the city centre of Vezprém, Hungary. World Landscape Architect. https://worldlandscapearchitect.com/the-reconstruction-of-the-city-centre-of-veszprem-hungary/#.XhSsiHduJPb

actions were supposed to be the result of collaboration between the public and relevant responsible entities [29]. While according to the policies of Har Ye Kan, Ann Forsyth and Peter Rowe the following bodies should be involved in the implementation process: the Ministry of Housing and Urban-Rural Development; the Ministry of Law; the State Council; the National People's Congress; planning commissions and bureaus from the provincial to local district levels; real estate developers; property managers; neighbourhood small and medium businesses; sub-district offices and local community service providers; and residents' and homeowners' associations [28].

Aside from government funding, proposals also need to address financial issues and provide strategic solutions to ensure the successful implementation of the latter. For example, in a study of the city of Voronezh, the authors emphasized the regulatory role of state and local government institutions in improving the preservation of buildings of historical and cultural value by modifying the legal framework and adapting relevant policies, so as to encourage investors to support the renovation of such infrastructures [42]. Moreover, another study on Madrid suggests that government funding be provided in the form of privilege tax for homeowners (Perez and Walker 2018). Yet another study on the British city of Birmingham recommends changes to rent payments and their taxation policies aimed at promotion of interests and favorable conditions for small business operating in the quarter and the balanced development and allocation of historic and trading companies [31]. The use of special mechanisms by the Government can also play a crucial role in ensuring the inviolability of structures and neighbourhoods of historical and cultural value. Such tools can be the creation of special reservation areas, the imposition of fines, the dissemination of care-promoting announcements and recommendations [43,38]. A well-developed general plan also plays a crucial role within the framework of financial management, since it can demonstrate the economic potential of a given urban environment, thereby promoting its image and attracting investments [33].

Conclusion

A generalized analysis of the studies conducted in Yerevan and the proposals presented based on them as well as the studied examples of international practice allow us to systematize the main positive and negative trends shown in the research outcomes.

Summing up the studies conducted in Yerevan, it should be noted that comprehensive approaches have already been used to achieve the utmost effective result for the reconstruction of quarters. A comprehensive study was carried out to reveal the history of the formation of the selected areas, identify the sources of the problems as well as find preserved archival and documentary materials related to the quarters. The current situation has been thoroughly studied, and drawings have been compiled showing the functions of the existing structures, their number, and the territory that they occupy. And in the submitted project proposals, an attempt was made to solve the identified existing problems, as well as finding ways to overcome them as effectively as possible. Particular attention has been paid to the implementation of projects, financial calculations, and suggestions of certain ways to implement them more efficiently.

Nevertheless, the study and analysis of a variety of international works allow us to identify flaws in the work done and raise questions that require further attention.

First of all, it is necessary to mention the local nature of the proposals for the reconstruction of the quarters. The identified problems and their solutions were not fully considered in the overall context of the city center. With the main emphasis on the newly proposed development, the issues of the existing and preserved buildings have not been sufficiently studied, moreover, clear principles and approaches to their modernization or reconstruction processes have not been presented. The proposed projects did not consider the natural climatic features of the territory, the environmental and energy efficiency problems of construction and improvement elements. The challenges of engineering infrastructure present in the areas have not been adequately studied, and engineering estimates for newly added development have not been implemented. The proposals did not include measures to identify opportunities for the restoration of the socially enriched environment of traditional

Yerevan yards. In the process of developing project proposals, the involvement of the population has not been sufficiently organized, the opinions of the municipal authorities and potential investors have not been considered properly. Additionally, in developing an economic strategy for implementing projects, the main emphasis has been on the principle of addressing the necessary costs of reconstruction at the expense of the new development. Such a unilateral approach, as well as an incomplete observation of the economic factor (in separate parts of the center), has often led to the need for obligated additional development.

The observations outlined as well as the comprehensive study of international examples show that further research and proposals related to the process of reconstruction of residential quarters of the city center of Yerevan need to be supplemented with the following principles and approaches.

To have a more thorough analysis, contributing to further research and design, it is necessary to subject the process to certain additions. Based on the results of the already conducted surveys, field observations, historical, archival, documentary, statistical and program-related documents, the following should be further studied:

- the history of the origin and formation of quarters,
- climatic conditions of the area,
- population growth trends and predictions,
- social relationships and real demands of residents in neighbourhoods,
- the presence and status of general plans, the structure of development and street networks,
- existing buildings, their chronology, architectural and structural characteristics, authenticity, historical and cultural significance, degree of preservation,
- social perceptions of the urban environment and its identity.

On the basis of a generalized analysis of the conducted research, the acquired information and the observations made, all the fundamental problems have to be revealed, that relate to:

- protection of society,
- technical safety of the buildings,
- road and engineering infrastructure,
- provision of sanitary and hygienic conditions in sites and buildings,
- presence of green zones and public spaces,
- preservation of urban heritage.

As a result of the analysis carried out based on the conclusion of problems and a comprehensive assessment of the situation, it is necessary to compile:

- classifications based on different characteristics of quarters,
- approaches to evaluating the conservation opportunities of previous urban development ideas,
- systems for assessing the subsequent use of neighbourhood structures,
  models of resident participation in reconstruction processes, ways to implement them.

The results of research and analysis show that the following approaches should be introduced in proposals for quarters:

- detailed design of general plans,
- implementation of multifaceted variant development,
- reflection of social demands in emerging solutions of the environment,
- provision of favorable conditions for social interactions,
- solutions to the problems faced by vulnerable groups of the population,
- creation of a social diversity of housing stock,
- the increase of green zones and public spaces,
- improvement of functional and planning parameters of housing, sanitary and hygienic provision,

- regulation of the functional composition of public service structures,
- enhancement of the aesthetic and artistic qualities of the environment.

In order to ensure the smooth implementation of the developed project proposals, to maintain the adequacy of the applied principles, as well as to obtain a better environment for life, special attention should be paid to the program implementation models towards:

- the improving urban environments and quality of life,
- the use of the full potential of the urban economy in the process,
- the involvement of additional sources of financing besides government and local self-governing bodies,
- the development of clear plans for legal, financial, and tax policy activities.

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ASSESSMENT OF THE STRESS-STRAIN STATE OF STRENGTHENED BUILDINGS IN SEISMIC REGIONS TAKING INTO ACCOUNT SOIL DYNAMIC PARAMETERS

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Abstract: *The main objective of the article is to assess the stress-strain state of building structures under seismic action taking into account the dynamic characteristics of the soils. As well as an assessment of the effectiveness of strengthening method of masonry building based on the Time History Analysis of the bearing capacity of structures.*

During the study a real existing masonry building is chosen. The building is modeled with the Lira-SAPR computer software with usage of the proposed strengthening method. Then, with the help of full-scale tests, the geophysical characteristics have been determined, as well as the prevailing period of the soil. Based on the existing engineering-geological and obtained by us geophysical data, the synthetic accelerogram corresponding to the masonry building soils have been chosen. The Time History Analysis of the building structures under seismic action have been carried out using previously obtained accelerogram, where the results have been compared with the standard Response Spectral method. And, finally, based on a comparison of various methods for assessing the bearing capacity, the effectiveness of building strengthening has been evaluated. The results of this study can assist the structural engineer in making better decisions for future design decisions.

Keywords: *seismic impact, soil dynamic parameters, structural system, stress-strain state, strengthening, masonry building.*

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Introduction

There are many different calculation methods for analysis of stress-strain state of building structures, as well as for assessing the bearing capacity of structures. The main method for computation of buildings is the Response Spectral method. This method depends on the soil category. Time History Analysis directly depends not only on the soil category, but also on the period, since the accelerogram includes all parameters that depend on the dynamic characteristics of soils. One of the main difficulties in the calculation is the selection of the correct accelerograms for the calculation of buildings. Until now, various countries of the world use a different approach when choosing these accelerograms. For a correct assessment of the bearing capacity of structures, it is necessary to set such accelerograms that correspond to the construction site under consideration.

Therefore, one of the main parameters influencing on bearing capacity of buildings and structures and the stress-strain state of their structures during seismic action, is the subsoil of the building. Usually, for assessment of the bearing capacity of the subsoil they are limited to engineering and geological studies of the soil. But in special cases it is also necessary to have the geophysical characteristics of soils. In some building codes it is necessary to compare the periods of the building and the soil. The structural system of a multistory building according to building codes of Armenia[1] should be chosen so that the conditions $T_1 > 1.3T_0$ or $1.3T_1 < T_0$ are met, where T_0 is predominant period of the ground, and T_1 is the first mode free oscillations

[1] HHSHN 20-04-2020. Yerkrasharjadimackun shinararutyun. Nakhagtsman normer, Yerevan, 2020 (in Armenian).

period of the structures. At the same time, it is necessary to compute the structures with implementation of accelerograms, taking into account the subsoil dynamic characteristics.

Among numerous problems of modern urban development, the problem of strengthening, retrofitting and reconstruction of existing buildings and constructions in current construction takes one of leading places. Issues are very actual as the majority of different types of buildings constructed in Republic of Armenia are not satisfying requirements of operating building codes[2,3,4] [1]. With the global scientific and technological advance of the recent years the earthquake resisting building code of the RA have undergone to certain changes, as a result of which the buildings and constructions erected years ago do not meet the current demands of operating building codes. The current demands of seismic code have been made strict, so the bearing systems of the many public and civil buildings, erected in the period of the USSR, are subject for strengthening and reconstruction.

The main goal of the research work presented herein, is the investigation of structural behavior in action of static and dynamic loads of the existing college building with masonry walls by FEM analyses taking into account soil dynamic parameters, as well as an assessment of the effectiveness of strengthening building structures based on the analysis of the bearing capacity of structures. The building's structures were designed in the years 1970-1980 in accordance with the structural concepts of that period. It was designed for earthquake loads, according to the provision of old codes, much lower than those require by current code.

Materials and Methods

Initial data for the masonry building

The building of the State Agricultural College named after G. Aghajanyan, located at 5 Student Street, Nor Geghi community, Kotayk region, RA, has been selected for the project (Fig. 1).

Fig. 1. *General and interior views of the building*

College building is a four-storey building with load bearing stone walls. It has a complex outline, about 51.5x16.5m axial dimensions in the plan. The standard floor height of the building is 3.2m (floor height was observed from floor to floor). The building has two staircases inside. The solution of the structural system of the building is given with 4 longitudinal and connecting transverse walls of stone structures, with partial reinforeced concrete frames in the internal longitudinal walls, with horizontal hard disks of the midfloor slabs and the roof slab. The axial distances of the longitudinal walls of building are 6.4m, 3.3m and 6.4m, respectively, and the transverse walls are installed at a distance of 17.0m (Fig. 2).

[2]HHSHN 20-04-2020. Yerkrasharjadimackun shinararutyun. Nakhagtsman normer, Yerevan, 2020 (in Armenian).
[3]HHSHN 20.06-2014, Shenkeri yev karrutsvatskneri verakarrutsum, verakangnum yev uzheghatsum. Himnakan druytner, Yerevan, 2014 (in Armenian).
[4]HHSHN 52-01-2021, Betone yev yerkatbetone karrutsvatskner. Nakhagtsman normer, Yerevan, 2021 (in Armenian).

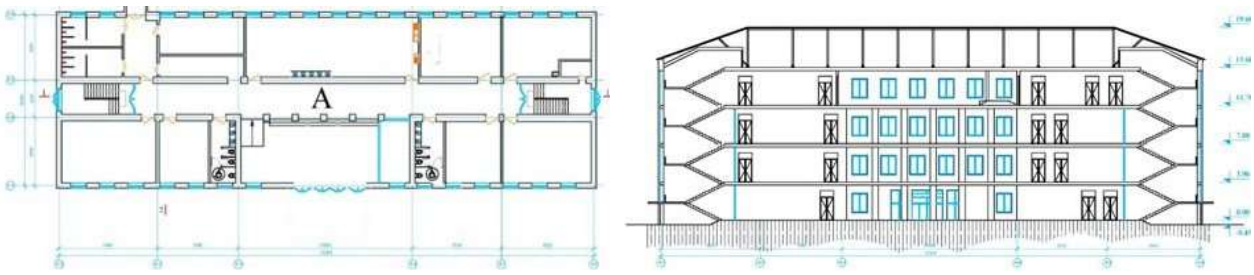


Fig. 2. *The first floor plan and section of the uilding*

The observation of the side facade of the building shows that there are beam foundations made of rubble masonry with basalt stones. The walls are made of "Midis" type load bearing stone walls using tuff stones and lime mortar, 55cm thick. External walls are made of dressed tuff stones. The partial reinforced concrete frame used in the internal longitudinal walls is made of in-situ reinforced concrete, the columns have a square cross section of 40x40cm, they are plastered with mortar. Some of the columns are plastered to a 50cm diameter circle. The beams of the internal reinforced concrete frames have a rectangular section with 50x60cm. Slabs are made of hollow core reinforced concrete panels and the part of fourth floor slab is made of in-situ reinforced concrete. The staircases consist of prefabricated reinforced concrete stairs, which rely on steel stringers. The roof is multi-sloped with external drainage system and it is constructed with timber rafter system as well as covered by steel profile sheeting.

The main defects of the building

The building with its structural-planning solutions does not comply with the requirements of earthquake resistant construction codes applied in RA related to the buildings with bearing stone walls, moreover, it is worth mentioning that there were no anti-seismic measures taken in the structural system of the building. The distances between the transverse walls in the structural system of the building considerably exceed the requirements of current codes, for this type masonry the permissible size is 6m. The some of transverse bearing walls in transverse direction is not located on the full width of the building (they are interrupted). In the transverse walls of the building there are openings which are too big in size. Slab panels are installed closely to each other, without anti seismic belts. The width of the piers of external bearing walls and of corner parts is considerably smaller than the values required by earthquake resistant construction codes, for this type masonry the width of piers should be not less than 2m and for the piers of corner parts the required width is 2.3m. The number of floors does not meet the requirements of the current codes, for schools and colleges it can be no more than three. Overall, the building is in a sufficient condition in case of static impact, and in case of an earthquake weaker than the designed one. The building condition is insufficient according to operating earthquake resistant construction building code. In order to provide enough strength and stiffness for the building and to minimize the possible damages and decay in the structure in case of seismic impact, it is necessary to provide a completely new structural system for the building. The new structural system should be designed so that it entirely gets the possible seismic load [1-12].

Some features for strengthening of masonry buildings in RA

According to operating codes it's permitted to increase the level of seismic resistance in buildings instead of the strengthening. The quantitative value of "Increment the seismic resistance" is the coefficient Ks ($0.5 < Ks < 1$) that is equal to $Ks = \sum S / \sum Sn$, where $\sum S$ is the sum of seismic forces at the upper level of the basis (Seismic Base Shear) that is resisted by a building as a result of strengthening ("Increment of seismic resistance), $\sum Sn$ is the sum of seismic forces at the same level that is determined by calculation according to operating codes.

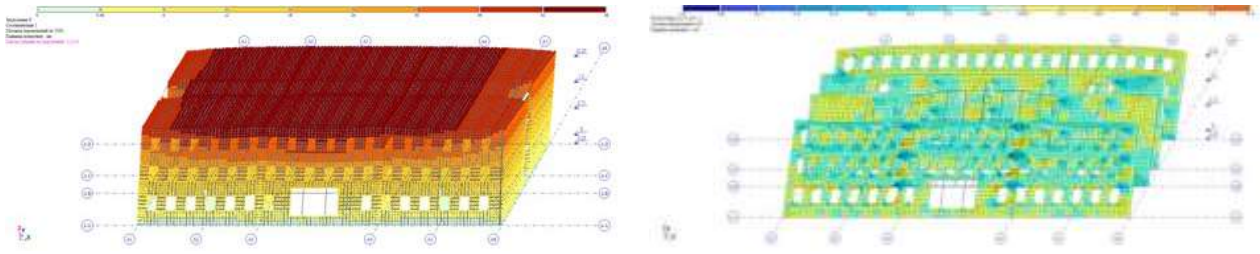
Modeling of multi-story masonry building by software and analysis of the stress-strain state of the masonry structures without strengthening

The building has been modelled under seismic actions by operating building codes having in mind the existing bearing system (without top floor), with deficiencies of the structural system and real soil parameters.

Initial data:

1. The calculations are made to increase the level of seismicity (for three floors bearing system, Ks = 0.5).
2. The calculations of the building are made by Lira SAPR 2017 software. The building is calculated as a 3D model, from vertical loads and seismic impact, in the direction of the digital and letter axes of the building [9-11].
3. The characteristics of the materials of bearing structures in the FEM model:
   - concrete B25 (strength of compression 25 MPa),
   - heavy concrete, average density R = 2500 kg/m^3, modulus of elasticity E_b = 3060000 t/m^2,
   - stone walls "Midis", modulus of elasticity E = 96000 t/m^2, average density R = 1760 kg/m^3.
4. The general parameters for calculation from seismic impact:
   - seismic zone (0.3g) – 2,
   - soil category – II, soil conditions coefficient – K_0 = 1,
   - building and structure permissible damage coefficient – K_1 = 0.6.
5. The calculation is made with the following loads:
   - Load 1 - self weight of the bearing structures,
   - Load 2 – dead load,
   - Load 3 – live long term load,
   - Load 4 – live short term load,
   - Load 5 – seismic impact in the longitudinal direction for the determination of the stresses,
   - Load 6 – seismic impact in the transverse direction for the determination of the stresses,
   - Load 7 – seismic impact in the vertical direction for the determination of the stresses.
6. As the results of the calculation are presented: period of oscillation, displacements and storey drifts, main tensile stresses in the "Midis" type walls (Fig. 3).

According to camputations the oscillations period values of the first mode are: by the axis X – T_1 = 0.246s, by the axis Y – T_1 = 0.481s:



a) *b)*

Fig. 3. *a) - Displacements and storey drifts from seismic impact by the axis Y,*
b) - The main tensile stresses from seismic impact by the axis X

Maximum storey drift Δy, max = 17.10mm > [Δ] = H/600 = 3750/520 = 7.2mm. For dressed stones and "Midis" type masonwork the maximum value of permissible storey drift is h/600. The main tensile stresses in the masonwork is σρ = 91.9 t/m^2 > [σρ] = 20.0 t/m^2 (Table 9, point 4a, RABC IV-13.01-96 Stone-reinforced stone structures). The calculations have shown that the condition is not met.

Modeling and analysis of the stress-strain state of the building with strengthenings

To increase the level of seismic resistance, it is planned to demolish the fourth floor, increase the cross-section of the columns, reinforce the load-bearing walls with shotcrete and add new monolithic reinforced concrete walls and frames in the transverse direction, dismantle the staircase and build a new one on site from in-situ reinforced concrete, reinforce the floor slabs with a reinforced concrete layer 50mm thick. The strengthened plan for the building is shown in Figs. 4-5 [1].

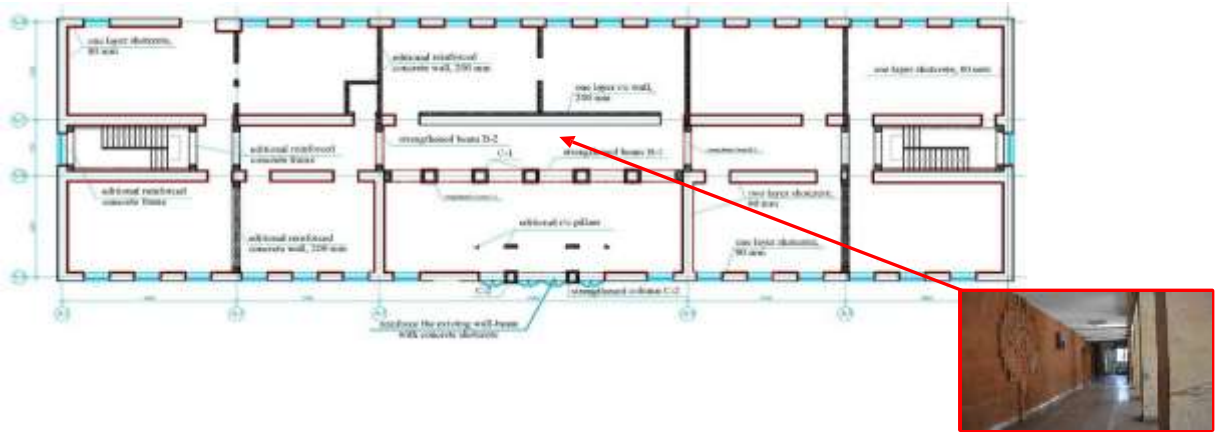


Fig. 4. *The strengthened plan for the building and interior view*

Initial data:

1. The calculations are made to increase the level of seismicity (for three floors bearing system, Ks = 0.5).
2. The calculations of the building are made by Lira SAPR 2017 software. The building is calculated as a 3D model, from vertical loads and seismic impact, in the direction of the digital and letter axes of the building [9-11].
3. The characteristics of the materials of bearing structures in the FEM model:
   - concrete B25 (strength of compression 25 MPa),
   - heavy concrete, average density R = 2500 kg/m^3, modulus of elasticity E_b = 3060000 t/m^2,
   - one-layer shotcrete (strength of compression 25 MPa), thickness 8cm, average density R = 2100 kg/m^3, modulus of elasticity E_b = 2240000 t/m^2,
   - two-layer shotcrete B25 (strength of compression 25 MPa), thickness 6cm, average density R = 2100 kg/m^3, modulus of elasticity E_b = 2240000 t/m^2,
   - stone walls “Midis”, modulus of elasticity E = 96000 t/m^2, average density R = 1760 kg/m^3.
4. The general parameters for calculation from seismic impact:
   - seismic zone (0.3g) – 2,
   - soil category – II, soil conditions coefficient – K_0 = 1,
   - building and structure permissible damage coefficient – K_1 = 0.6.
5. The calculation is made with the following loads:
   - Load 1 - self weight of the bearing structures,
   - Load 2 – dead load,
   - Load 3 – live long term load,
   - Load 4 – live short term load,
   - Load 5 – seismic impact in the longitudinal direction for the determination of the stresses,
   - Load 6 – seismic impact in the transverse direction for the determination of the stresses,
   - Load 7 – seismic impact in the vertical direction for the determination of the stresses.
7. As the results of the calculation are presented: period of oscillation, displacements and storey drifts, main tensile stresses in the “Midis” type walls (Fig. 6-7).

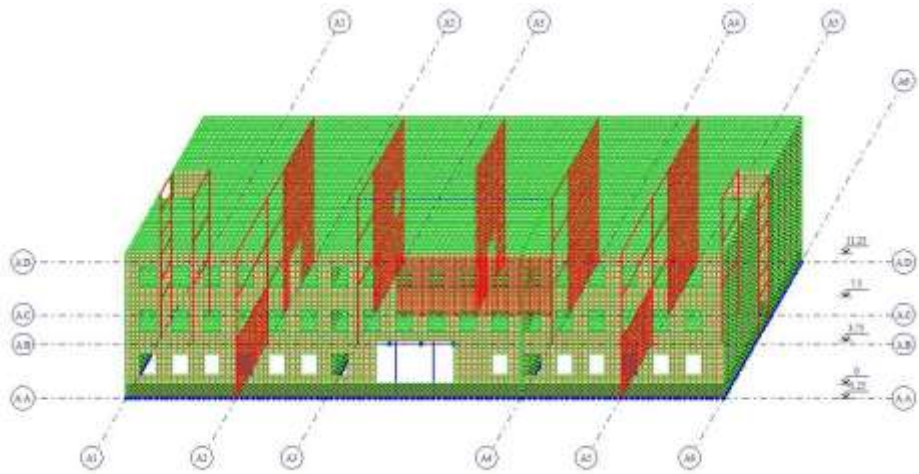
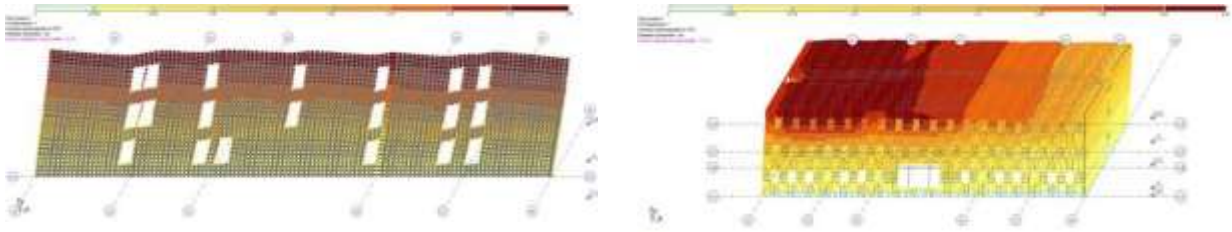


Fig. 5. *The new bearing system of the building with additional elements*

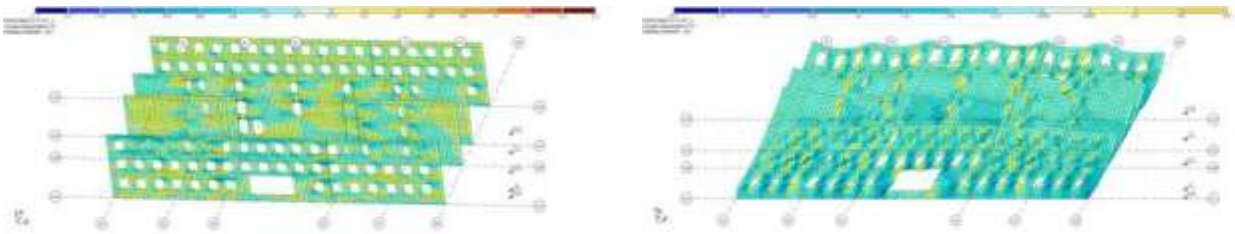
According to camputations the oscillations period values of the first mode are: by the axis X – $T_1 = 0.099$s, by the axis Y – $T_1 = 0.14$s. As the calculation results show, the oscillations period values decreased by 2.5 times. For buildings and structures with largely uniform distribution of rigidities and masses along the height, if the oscillations period value of the first mode is $T_1 < 0.4$s only the first oscillation mode is considered[5].



a) *b)*

Fig. 6. *a)- Storey drifts from seismic impact by the axis X,*
b) - Storey drifts from seismic impact by the axis Y

Maximum storey drift Δx, max = 0.70mm < [Δ] = H/600 = 3750/520 = 7.2mm. Maximum storey drift Δy, max = 2.10mm < [Δ] = H/600 = 3750/520 = 7.2mm. For dressed stones and "Midis" type masonwork the maximum value of permissible storey drift is h/600. The calculations have shown that the condition is met.



a) *b)*

Fig. 7. *a) - Storey drifts from seismic impact by the axis X,*
b) - Storey drifts from seismic impact by the axis Y

[5]HHSHN 20.04-2020, Yerkrasharzhadimatskun shinararutyun. Nakhagtsman normer, Yerevan, 2020 (in Armenian).

The main tensile stresses in the masonwork in ***longitudinal direction walls*** is $\sigma\rho=17.5$ t/m^2 < $[\sigma\rho]=20.0$ t/m^2 (seismic impact by the axis X), $\sigma\rho = 6.35$ t/m^2 < $[\sigma\rho] = 13.0$ t/m^2 (seismic impact by the axis Y), (Table 9, point 4a, RABC IV-13.01-96 Stone-reinforced stone structures).

The results of the calculations show that the new bearing system developed for the building satisfies all the requirements of the seismic building codes. We can note that the strengthening project can be developed based on the proposed bearing system.

Synthetic accelerograms for structural analysis

According to archival data the Nor Geghi community of the RA is located on the right bank of the Hrazdan River, in the southern part of the Yeghvard Plateau, in the geological structure of which columnar andesite-basalts of the Lower Quaternary age play the main role. Andesite-basalts are fine-grained, porous and fissured, which on the territory of the plateau plane are covered with deluvial and eluvial deposits of the Upper Quaternary age, represented by sandy loam and loam, with a content of andesite-basalt fragments of 20–40%. Their thickness varies about 10m, sometimes reaches 30m.

According to the specified characteristics, the type of soil in terms of seismicity belongs to the 2nd category, what was accepted in the calculations of buildings. An instrumental determination of the geotechnical parameters of the soil was carried out to check the accuracy and efficiency of the work performed. For geotechnical investigation fieldwork were used Multichannel Surface Wave Analysis (MASW) method. It is evaluating ground stiffness by measuring shear-wave velocity (Vs) of subsurface in the most common depth range of 0-30 meters. This method accepted in the seismic building code of Armenia. MASW first measures seismic surface waves generated from various types of seismic sources - such as sledge hammer, analyzes the propagation velocities of those surface waves, and then finally deduces shear-wave velocity (Vs) variations below the surveyed area that is most responsible for the analyzed propagation velocity pattern of surface waves. Shear-wave velocity (Vs) is one of the elastic constants and closely related to Young's and shear moduli. Under most circumstances, Vs is a direct indicator of the ground strength (stiffness) and therefore commonly used to derive load-bearing capacity.

In practice, surface wave registrations (MASW) were carried out with the help of an Italian-made digital seismic station PASI GEA24.

In the upper layers of the engineering-geological section, the dynamic characteristics of the ground were interpreted as the mean velocity of transverse waves Vs30. The values of the velocities of shear waves are obtained on the basis of four tests (Vs1 = 827.8 m/s, Vs2 = 837.6 m/s, Vs3 = 716.6 m/s, Vs3 = 755.0 m/s). The shear waves' average velocity of the studied area's ground is $700 < Vs < 840$ m/s, according to HHSHN 20.04-2020 heterogeneous ground substrate soils correspond to soil category II.

According to the results of experimental data from the database of open accelerograms accepted for the software, a suitable accelerogram was selected for further calculations. Directory DBN_ACCEL contains eight sets of three-component synthesized accelerograms. Every file of accelerogram has a *.txt extension and is an ordinary text file. The file contains an array of acceleration values (m/s^2).

Table 1. Parameters of three-component synthesized accelerograms

Name of accelerogram file	Range of prevailing periods Tpr, s	Amplitude of max acceleration A, m/s^2	Step of discretization Ät, s	Number of points N	Time of accelerogram
Vb1r	0.1 - 0.3	1.485	0.0125	10500	131.2375
Vb1t	0.1 - 0.3	1.298	0.0125	10500	131.2375
Vb1z	0.1 - 0.3	0.972	0.0125	10500	131.237
vb1_mod29	Vb1r + Vb1t + Vb1z		0.0125	310500	131.237

The results of the calculations show that the calculation with the selected accelerogram gives a more accurate picture of the stress-strain state of the bearing system of the building. At the same time, it should be noted that it is desirable to make calculations with several different accelerograms, given that they narrowly describe the possible expected earthquakes.

Results and Discussion

Below (Table 2) the values for the main dynamic parameters of the building performed by different models is showed.

Table 2. The main dynamic parameters of the building performed by different models

	Total masses (t)	Base Shear		Displacement		Storey drift		Tensile stresses			
		Px (t)	Py (t)	X (mm)	Y (mm)	Δx (mm)	Δy (mm)	LW by X (t/m^2)	LW by Y (t/m^2)	TW by X (t/m^2)	TW by Y (t/m^2)
Model 1 without strengthening	6602.5	2135	1995	12.0	48.0	4.1	17.1	91.9	82.4	74.5	262.0
Model 1 with strengthening	7657.3	1730	1815	1.9	4.6	0.7	2.1	17.5	6.35	5.07	20.3
Model 1 by accelerogram	7635.5	1780	1525	7.08	3.74	2.36	1.25	21.6	23.4	11.3	38.7

Comparative analysis shows that the results of the spectral analysis meet all the requirements of the operating building codes, but when calculations were made by the accelerogram the values of main tensile stresses in some parts of the masonwork can exceed the allowable values by about two times. Therefore, in order to increase the efficiency of the structural projects, it is necessary to make a calculation with at least three suitable accelerograms.

Conclusion

The correct choice of the method for analysis the stress strain state of the bearing structures, taking into account geotechnical investigation of the soils, will make it possible to more accurately assess the stress-strain state of building structures. In this case, the structural project will also be effective.

In the case of building strengthening, before developing the project of increasement the level of buildings seismic resistance it is often necessary to understand whether it is economically profitable to strengthen the building or it will be effective to build a new one. In general, when the cost of strengthening project exceeds 70% of the new construction, it is more expedient to build a new one.

The method presented in the work can be used to easily assess the geotechnical parameters of the soil without drilling, on the basis of which, using FEM analysis, it is possible to determine the expediency of strengthening the structures. Based on the results of the work, we can say that the parameters determined by the MASW method match the actual data for the investigation of the stress-strain state of the building structures, so the above method will allow to get rid of drilling work at the initial stage of the project, saving money and time.

Acknowledgements

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SCIENTIFIC AND EXPERIMENTAL SUBSTANTIATION FOR THE PRODUCTION OF FIREPROOF AND HEAT-RESISTANT MATERIALS FROM MAGNESIA-SILICATE ROCKS

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Abstract: *This article touches upon the technologies for fireproof and heat-resistant concrete production based on local raw materials: magnesia-silicate rock from the Sevan deposit, which can be used in thermal units to replace small-piece masonry bricks and figured elements. Raw materials were studied, the magnesia modulus was determined, chemical, radiographic, thermographic, and dilatometric analyses were carried out. To reduce volumetric shrinkage and porosity and convert clinoenstatite into forsterite, the rock was pre-baked in the presence of* MgO*. The proposed technology is low-power and urgent, especially in the energy crisis. Based on the mentioned rocks, multifunctional, cost-effective, fireproof, and heat-resistant forsterite materials have been developed, compressive strength ranges from 40 ... 60 MPa, the melting point of 1600°C, and heat resistance - 5 thermal cycles.*

Keywords: *fireproof and heat-resistant concrete, ultrabasic magnesia-silicate rock, clinoenstatite, forsterite, forsterite concrete, phosphate binder, low-power technology.*

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Introduction

In world practice, the construction of thermal units has traditionally been implemented with expensive fireproof and heat-resistant small-size brickwork and figured elements obtained from various raw materials through various technological, high-temperature processing and functionally graded coatings [1], which is labor-intensive and requires high-quality and high-value handiwork. The latter is because ensuring the effective implementation of technological processes in these units leads to the need to build structures with complex contours. Alternatively, the world's experience shows that due to the varying degree thermal deformability of brick [2] and masonry under high temperatures, the structures made from them typically require regular repairs and fail quickly, which leads to the interruptions, downtimes of thermal units and, in general, technological production processes performed in them, as well as to high material and labor costs. Using fireproof concrete in the construction of thermal units in various spheres of application will create an opportunity to exclude similar problems [3-8].

Compared to traditional fireproof bricks, fireproof concrete does not require expensive preliminary high-temperature treatments [9,10,12]. In the planned regimes, the conversion reactions that ensure fire resistance occur during the initial heating of the already-built units. The production of fireproof concrete and the corresponding structures based on it make up about 3-5% of the total volume of fireproof material production. This indicator is high in many industrialized countries, such as the USA, England, France, Germany, Austria, Japan, etc. [11]. The first reason for the relatively low level of fireproof concrete consumption is the lack of high-quality fillers, binders, and various additives. The second is that in the technology of fireproof concrete, besides the stringent requirements for the chemical and mineral composition of the raw materials, there are other strict requirements, such as ultra-purity of fillers and additives (complete exclusion of admixtures), precise grain sizes, high precision dosing, competent selection of binders, their efficient and strict combination with additives, etc. In various countries, the solution to these issues is provided by organizing the production of fireproof dry mixes for concrete.

Special fireproof cement (alumina, super-alumina), liquid glass, phosphate materials, Portland cement mixed with special additives, etc. are used as binders in these mixtures.

Materials and Methods

RA has abundant raw material reserves, including aluminosilicate and magnesium silicate rocks, which are used in the production of fireproof and heat-resistant materials. There are more than a dozen mines of the latter. These rocks contain dunites, serpentinites, peridotites, talc, etc. These mines are on the northwestern shore of Lake Sevan and provide valuable raw materials for high-temperature material production. Dunite rocks from the Shorzha mine were used in this research.

The following chemical binders are used in fireproof and heat resistant concretes: H_3PO_4 solution with a density of 1.6 g/cm^3, magnesium and sodium acid phosphates - $Mg(H_2PO_4)_2$, NaH_2PO_4.

Main part

The primary demand for fireproof materials in Armenia was met by the use of fireproof bricks supplied by Russia and Ukraine.

Through investigations conducted in RA beginning in 1986, fireproof concrete compositions were produced, and their qualities were researched. Achievements recorded during research are presented in many scientific papers [6-7,14,16-17,19-21]. For concrete and granular fireproof materials, the ultrabasic rocks of the Sevan basin were used as essential raw materials. This research was carried out in accordance with the existing standard methods. However, due to some objective and subjective reasons, the research in that direction was stopped, but the problem remained relevant. The availability of raw materials and the high cost of imported raw materials fueled the continuation of these projects. Analyzing the existing data, one might confirm that the deposits of the Sevan region, where sufficient reserves are available, are complex combinations of different rocks, including peridotites, pyroxenes, dunites, and serpentinites, which are mainly composed of magnesium orthosilicate ($2MgO \cdot SiO_2$ - forsterite) and metasilicate ($MgO \cdot SiO_2$ - clinoenstatite or enstatite) and are distinguished by the complexity of the mineral composition.

The mineral composition of superbasic rocks includes: olivines composed of orthosilicate ($2MgO \cdot SiO_2$) and fayalite ($2FeO \cdot SiO_2$), pyroxenes composed of enstatite or clinoenstatite, hypersthene ($MgO \cdot FeO \cdot 2SiO_2$), diopside ($CaO \cdot MgO \cdot 2SiO_2$), spinel minerals composed of chromite ($FeO \cdot CrO_3$), magnetite ($FeO \cdot Fe_2O_3$), magnesium hydrosilicates, the product of autometamorphism of olivine and pyroxene. The main minerals of this group are: anthophyllite ($Mg(OH)_2Si_8O_{22}$), talc ($Mg_3(OH)_2Si_{14}O_{18}$), serpentine ($Mg_3(OH)_4Si_2O_5$). When serpentine is heated to 600-650°C, it decomposes and removes water, increasing the porosity to 25-30%. Forsterite and amorphous silica soil are formed via decomposition.

$$2(3MgO \cdot 2SiO_2 \cdot 2H_2O) = 3(2MgO \cdot SiO_2) + SiO_2 + 4H_2O.$$

Free silica reacts with forsterite to form clinoenstatite when the temperature is raised to 1200-1400°C.

$$2MgO \cdot SiO_2 + SiO_2 = 2(MgO \cdot SiO_2).$$

The material's porosity decreases, and at 1400°C it stabilizes, reaching about 14–18%. This reaction is accompanied by significant material shrinkage (21.1%) [14, 15]. Due to the significant amount of serpentinite in dunite and the volumetric changes caused by it, it is advisable to calcine the rock beforehand, including MgO as an additive, to reduce the volumetric shrinkage, reduce the porosity, and convert the clinoenstatite to forsterite.

$$Mg_3(OH)_4Si_2O_5 + MgO = 2Mg_2SiO_4 + 2H_2O.$$

For the forsterite formation from pure serpentinite, it is theoretically vital to introduce a 12.6% additive [13, 16, 17]. Meanwhile, because the reaction between clinoenstatite and magnesium oxide occurs in the solid phase and does not proceed to the end, magnesium oxide is added more than the calculated amount (about 20–25%).

However, the low concentrations of iron oxide in the rock must be replaced with magnesium ferrite, a compound with a relatively high melting temperature, which reduces the fire resistance slightly and causes the following reaction:

$$Fe_2O_3 + MgO = MgFe_2O_4.$$

If we characterize the magnesium silicate rocks according to the forsterite modulus $M_f = \frac{MgO}{SiO_2}$, we find that compared to the technological composition of forsterite, they represent different values as raw materials (for forsterite $M_ф = 1.335$), with a melting temperature of 1890°C. The characteristic properties of some natural minerals are presented in Table 1.

Table 1. Some natural minerals and their properties

Mineral name	Formula	Composition, %				Real density, g/sm^3	Molecular mass	Melting temperature, °C
		MgO	SiO_2	FeO	H_2O			
Forsterite	$2MgO \cdot SiO_2$	57.9	42.7	-	-	3.21	140.7	1890
Fayalite	$FeO \cdot SiO_2$	-	29.5	70.5	-	4.07	203.7	1065
Enstatite	$MgO \cdot SiO_2$	40.2	59.8	-	-	3.16	100.38	1557
Serpentite	$3MgO \cdot 2SiO_2 \cdot 2H_2O$	43.7	43.3	-	13.0	2.55	277.1	1515
Talc	$3MgO \cdot 4SiO_2 \cdot 2H_2O$	31.9	64.4	-	4.7	2.75	379.2	1450
Olivine	$2(MgFe)O \cdot SiO_2$	Variable				3.32	-	1300
Periclase	MgO	100	-	-		-	40	2800
Quartz	SiO_2	-	100	-		2.68	60	1710

Following a preliminary analysis of the rocks' properties, research was implemented on producing refractory and heat-resistant materials from magnesium silicate rocks, and evaluating the rocks as fillers used in their compositions [6, 7, 15, 18, 20].

Results and Discussion

For the production of refractory and heat-resistant forsterite materials, several magnesium silicate rocks were used in our research, which are rich in magnesite and magnesite-dunites. Some rocks, such as serpentinite, particularly serpentinized dunite, and peridotite, do not possess the properties of fireproof forsterite raw materials due to an insufficient quantity of magnesium oxide (37% - 42%).

The chemical compositions and radiographs of two dunite rock samples from the Shorzha deposit in the Sevan basin are presented below (Table 2, Fig.1). X-ray analysis was carried out with an X-ray diffractometer - DRON 2, with Kα = 1.5418Å, voltage 25kV, power 20mA. X-rays were taken at an angle of 200 in the range of 6...60°.

Table 2. Chemical compositions of dunite rocks

Sample №	Content of components by mass, %									МФ
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Loss on ign.	
1.	36.74	0.27	0.93	8.87	0.33	37.52	trace	trace	15.04	1.02
2.	31.24	0.21	0.69	7.30	0.22	41.27	trace	trace	19.10	1.32

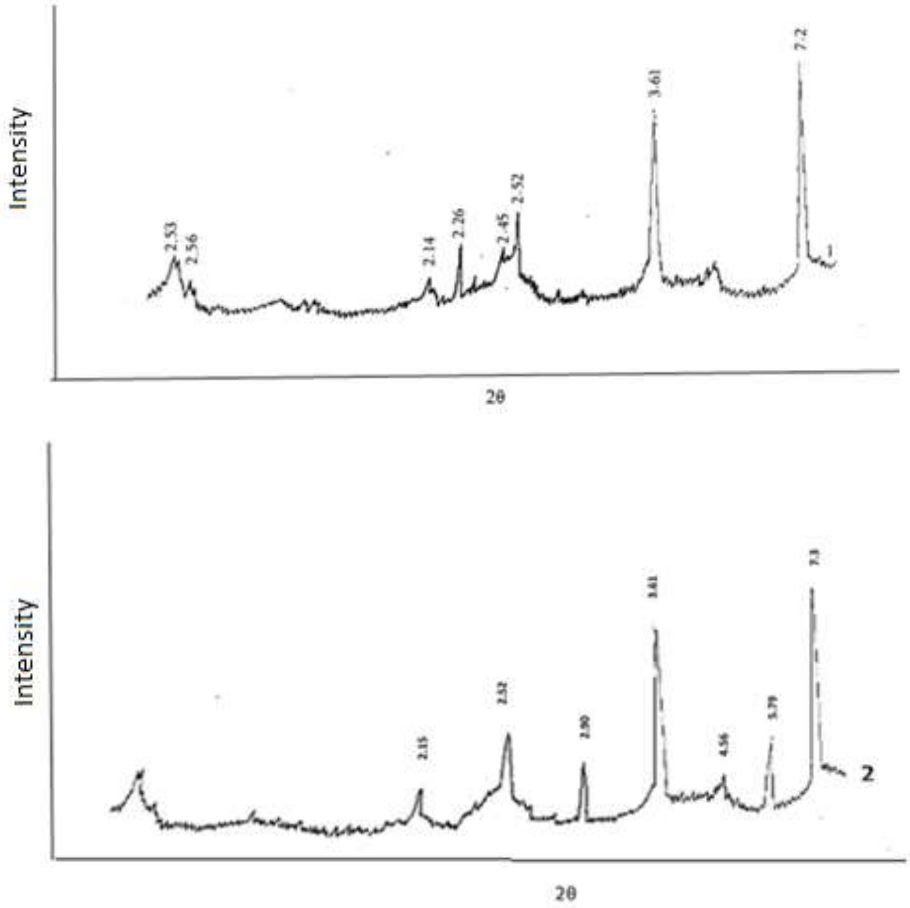

Fig. 1. *Dunite X-rays, 1- sample №1, 2- sample №2*

Considering the above-mentioned circumstance, during the preparation of the raw mix, magnesite powder from the magnesium-containing rocks of the same deposit is added to the main raw material to form forsterite [21]. For calcined forsterite refractory materials, only preliminary calcination of natural magnesium silicate rocks is required to prevent a significant degree of porosity and shrinkage during operation. This is in contrast to the two-stage procedure for obtaining refractory materials.

By using Sevan magnesium silicate rocks, the development of low-energy technologies can decrease the specific energy capacity of high-temperature materials [24]. Taking into account the fact that the basis for the forsterite refractory material preparation is the formation of the maximum quantity of magnesium orthosilicate, the optimization of the crystallization and synthesis conditions becomes vital for investigating the process's kinetics and phase changes. The phase changes were investigated under heat treatment by derivatographic, X-ray phase, petrographic, and dilatometric analysis.

X-ray analysis (Fig. 1) primarily identifies antigoritic serpentinite (7.20, 3.61, 2.52*Å)* and olivine (2.52, 2.45, 2.26 *Å*) in sample No1. The orientational content of the phases under the microscope is, respectively, 80 and 20%.

Antigorite (7.20, 3.61, 2.52Å), olivine (2.52, 2.45, 2.26Å) and hydromagnesite (5.79, 2.90, 2.15Å) were identified by X-ray analysis in sample No 2, where the content is ~ 8.5%. To explain the physicochemical processes occurring in the rock, the thermograph of serpentinized dunite of Sevan deposit is presented (Fig. 2).

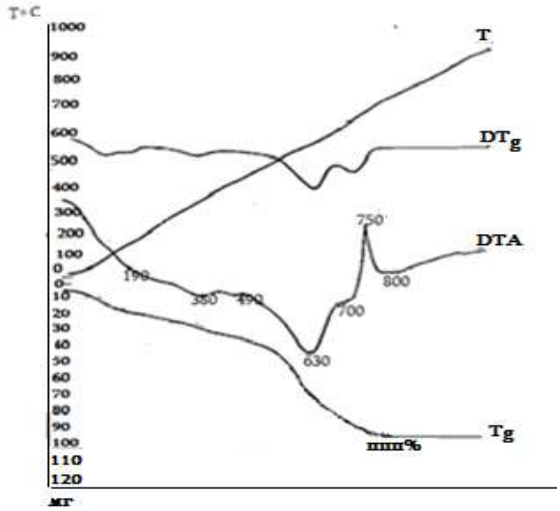

Fig. 2. *Thermograph of serpentinized dunite of Shorzha deposit*

The analysis was carried out on a 1500 FMOM derivatograph (Hungary), using calcined alumina as a standard.

Several mass loss endoeffects on the thermograph were observed during the derivatographic examination of the samples up to 750°C. When heated to a temperature of 190°C, the water in the macropores was removed from the rock samples.

The water in the large pores is free water, and its evaporation is not accompanied by volume reduction, i.e., rock shrinkage. The endoeffect at 380°C is most likely caused by brucite $Mg(OH)_2$ decomposition in small quantities.

When the temperature is raised to 700°C, first the water that is loosely bound in the capillaries and adsorbed on the surface of the crystals is removed, followed by the water that is removed from the layers of the rock crystal structure. The removal of this type of weakly bound water occurs intensively, leading to significant shrinkage.

However, mass loss occurs at a greater rate than volumetric shrinkage, resulting in a decrease in the rock's average density and a significant increase in strength due to the elimination of the "softening effect."

Decomposition of the antigorite crystal lattice occurs in the temperature range of 490...750°C, with a minimum of the endo effect at 630°C. Further phase changes in the dunite composition are evidenced by the exoeffect, with a maximum of 750°C. It is reasonable to assume that new minerals are crystallized from dehydrated and amorphized antigorite ($Mg_3(OH)_4Si_2O_5$), which is identified by X-ray analysis as olivine and pyroxene, forsterite (2.50, 2.44, 1.732, 1.472 Å), and enstatite (3:15, 2:87, 1:489 Å).

However, to reduce the shrinkage, produce high-quality sinters, and convert the metasilicate component to forsterite, an experiment was conducted to introduce magnesium oxide into the composition. X-ray analysis of dunite pre-calcined at 1450°C and (dunite + MgO) mixture after heat treatment at 600...1550°C was carried out.

The results of the analysis showed that in the presence of magnesium oxide, the number of crystalline phases increases to some extent. Free MgO reflexes are observed in the temperature range of 600...1350°C.

Traces of the latter and enstatite are observed even at the temperature of 1450°C and only at 1550°C the forsterite monocrystalline phase is synthesized.

The synthesis of a regular monocrystalline phase, forsterite, in (dunite + MgO) mixtures processed at 1450°C with a delay of at least one hour is possible, according to physicochemical research.

The implementation of the forsterite synthesis reaction also depends on kinetic factors, the main ones being the activation energy and the rate of the given process [16]. In the case of pyrosilicate reactions at high temperatures, the effect of activation barriers becomes insignificant, and the probability of the reaction proceeding under the given conditions is directly dependent on the reaction rate constant. The research analysis results for the production of dunite-phosphate concretes with low-energy technology allow to select the kinetic parameters of concrete having melting temperatures above and below the refractory limit (1580°C) (which was determined in the muffle furnaces of Naber, with a temperature range of 1350...1400°C, carborundum - 1450...1500°C and kryptol - 1700...1800°C).

The optimal indicators of the data (Table 3, A) can be used to obtain refractory and heat-resistant concretes: refractory (with refractory above 1580°C) and heat-resistant (with refractory below 1580°C) [22, 23]. Dunite-phosphate concrete samples with dense structures were subjected to X-ray analysis, which identified two primary crystalline phases, where forsterite $2MgO \cdot SiO_2$ was predominant.

Table 3. Optimal range of composition indicators with H_3PO_4(A), $Mg(H_2PO_4)_2$(B), NaH_2PO_4(C)

N	Content of ingredients, *%*		Drying temperature, °C	Melting temperature,°C	Compressive strength, *MPa*	Linear shrinkage, *%*
	Dunite cement	Phosphate binder				
A	50…70	8.9…9.0	250…300	1580…1870	60…70	0.85…2.25
	50…60	8.5…10.0	250…300	1580…1770	70…90	0.85…3.5
	50	8.5…10.0	200…300	1480…1580	65…110	2.5…3.5
B	40…50	15.4…21.0	110…250	1580…1870	30…42	0.85…2.25
	50	21.0…23.0	110	<1580	33…34	1.0
C	50	9.0…11.0	110…250	>1750	15…25	0.8…1.0

Conclusion

Considering into account the fact that there is no production of flammable and fire-resistant materials in RA, and these materials are in high demand, the task is set to develop high-temperature material components and production technology with local raw materials. To solve this problem, high-temperature dunite-phosphate dense concretes with a melting temperature of 1600°C, a compressive strength of 40...60 MPa, a porosity of 15. . .20% and a heat resistance of more than 5 temperature changes were developed on the basis of Shorzha magnesium silicate rocks.

The expediency of using Sevan magnesium silicate rocks as a filler in fireproof concrete was also confirmed, after preliminary calcining these rocks at a temperature of 800°C, because without the latter it is impossible to ensure proper quality due to the occurrence of significant shrinkage during calcination. High-temperature refractory and fire-resistant concrete can be obtained with great economic profitability in various sectors of the economy.

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HOLY ALL SAVIOR GHAZANCHETSOTS CHURCH IN SHUSHI AND "PROTECTION" OF CULTURAL HERITAGE IN AZERBAIJAN

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Abstract: *The paper presents the circumstances of the founding of the Holy All Savior Ghazanchetsots church (Gazanchetsots "Surb Amenaprkich") in the city of Shushi, its plan, spatial composition and decorations. The essence of the policy of the Azerbaijani authorities to change the ownership of the monument, its rejection from the Armenians, as well as the manifestation of vandalism against the church is revealed. The study was carried out by retrieving archival materials, discussing and conducting own original research. The aim of this study is to, based on voluminous materials on history and architecture of the Holy All Savior Ghazanchetsots church, stored in the National Archives of the Republic of Armenia, find out how Azerbaijan, in the face of political and scientific circles, with the help of what mechanisms, is trying to alienate the Cathedral of Shushi from the Armenian architectural heritage, appropriating Armenian history and culture.Presentation of the real architectural image of the the Holy All Savior Ghazanchetsots in Shushi and discussion of the events around it during and after the 2020 war is a way to draw the attention of international organizations for the preservation of monuments to the false policy of "cultural preservation" of Azerbaijan, trying to protect the building from further falsifications.*
Keywords: *the Holy All Savior Ghazanchetsots (Gazanchetsots "Surb Amenaprkich"), Armenian architectural heritage, Azerbaijani vandalism, distortion.*

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Introduction

Mesrop Taghiadyan reports on the Holy All Savior Ghazanchetsots Church of Shushi after visiting Shushi in the spring of 1821. According to that evidence, the Holy All Savior Ghazanchetsots Church of Shushi previously used to be wooden. He mentions that the existing wooden churches were replaced by stonebuilt structures [1]. The National Archives of the Republic of Armenia preserves an extensive material on the history of this church[1]. In the Soviet period publications on the history and architecture of Shushi city, the Armenian authors ([2,3,4,5] et al) presented in detail the religious structures and the Holy All Savior Ghazanchetsots church in Shushi. The Azerbaijani authors did not touch on this topic. Their works mainly present the fortification, urban planning, mosques, dwelling houses of Shushi [6,7]. The plan and volumetric-spatial professional examination of the church is fulfilled in a booklet authored by Manvel Sargsyan on the history of urban development of Shushi [8].

It should be noted that the Azerbaijani scientific community has no publications about the Gazanchetsots "Surb Amenaprkich" in Shushi both after the first Artsakh War and after the Second, in 2020. On the contrary, there were calls to usurp the heritage of Armenians and certain actions were taken to eliminate the traces of Armenians in Artsakh, particularly in Shushi.

On May 19-20, 2022, in Shushi, occupied by Azerbaijan, the Ministries of Culture and Nature Protection jointly organized a conference, the main topic of which was the restoration of the cultural image of "Karabakh region", and the role of culture in a peaceful dialogue. The subject brought up during the presentations and

[1] NAA, f. 56, l. 1, cs. 2145.

discussions referred to the reconstruction works to be carried out in the region "after the Armenian occupation and after the liberation of Karabakh". The conference was attended by Salim bin Muhammad al-Malik, President of the Islamic Organization for Education, Science and Culture (ISESCO), Baghdad Amre, Secretary General of the Turkish Council, Raymond Bondi, Secretary-General of the National Commission for UNESCO in Malta, Miguel Angel Moratinos, High Representative for the United Nations Alliance of Civilizations, Director of the International Foundation for Turkish Culture and Heritage Gunay Efendiyeva others[2].

The main goal of this study is to clarify, by presenting the architectural composition of the church, how Azerbaijan, in the face of political and scientific circles, with the help of what mechanisms, is trying to alienate the Cathedral of Shushi from the Armenian architectural heritage, appropriating Armenian history and culture, on the way to creating its own identity. To achieve this goal, voluminous materials on the history and architecture of the Holy All Savior Ghazanchetsots Church, stored in the National Archives of the Republic of Armenia, were studied, the architectural examination of the church was carried out and the current state of the monument after the second Artsakh war, when the city of Shushi came under the control of Azerbaijan, was described.

Materials and Methods

In the course of the study, materials from the National Archives of the Republic of Armenia on the church of the Holy All Savior Ghazanchetsots of Shushi were used, a thorough study and interpretation of which made it possible to clarify issues related to the design and foundation of the church. The bibliographic method of study, historical and comparative analysis, as well as original methods of research were applied. Materials related to Shushi and, in particular, the Holy All Savior, posted on Azerbaijani websites in 2021-2022, and publications of the "monument watch.org." website were also used.

Results and Discussion

Historical overview

The National Archives of the Republic of Armenia preserves an extensive material on the history of this church[3]. The time of construction of the Ghazanchetsots stone church on the place of the wooden structure is unknown. However, the stone church built in 1847 was already in a state of disrepair. According to the mentioned materials, it was a three-nave domed basilica covered with stone slabs or tiles. In the same year, Metropolitan Baghdasar began correspondence with the Synod of Etchmiadzin to obtain permission to renovate the church. During the four-year correspondence it is decided to build a new church on the previous site. But it took decades for the idea to materialize. During this time the belfry of the Holy All Savior Ghazanchetsots Church was built.

The idea of building a new church became relevant again in 1867. The architectural inspector of the city was asked to make a plan, a facade and a cost estimate of the church[4] (Fig. 1).

Believers and clergy expressed a desire for the church to be built on the example of the medieval Ani Cathedral, but the presented project had a different design. A number of remarks were made when approved by the superior inspectorate. The project was amended for a long time and approved in 1868. The lack of graphic documentation does not enable us to find out to what extent the temple is built in accordance with the design proposals. It becomes obvious that the Holy All Savior was built according to the plan. The inscription

[2] https://azertag.az/ru/xeber/Mezhdunarodnaya_konferenciya_v_SHushe_zavershila_svoyu_rabotu-43898 https://www.youtube.com/watch?v=IC6Zlgsy9SY https://www.youtube.com/watch?v=cCeFp9T3ob8
[3] NAA, f. 56, l. 1, cs. 2145.
[4] NAA, f. 56, l. 1, cs. 3618.

opened during the renovation in 1982 mentions the names of the architect who built the monument – Simeon Ter-Hakobyants, and master Avetis Yaramishyants [4] (Fig. 2).

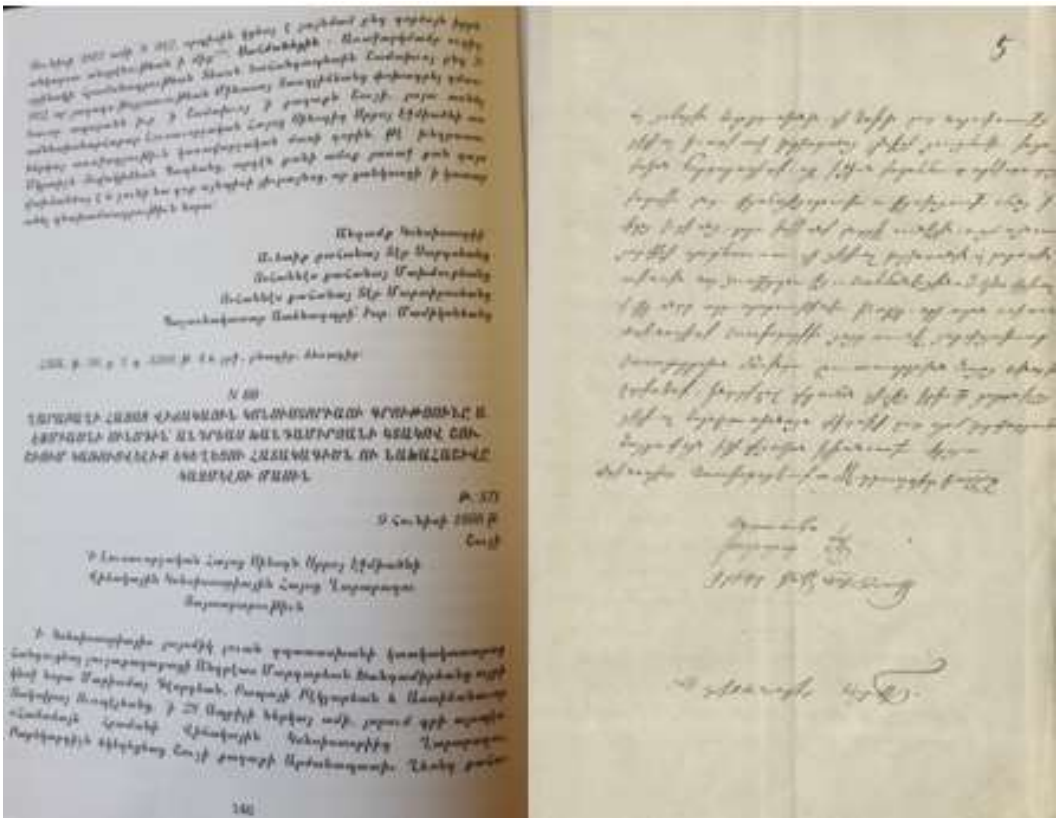


Fig. 1. *Materials stored in the National Archive of Armenia on the circumstances of the construction of the Holy All Savior Ghazanchetsots Church in Shushi. NAA, F 56, p.1, 2145*

Fig. 2. *The inscription engraved at the lower part of the church's bas-relief with the names of the master builder and architect*

The epigraph placed at the top of the southern portal also mentions that the temple was built with the donations of the parishioners of Shushi: the construction began in 1868 and was completed in 1887 (“Thanks to and by the mercy of Almighty God, this magnificent holy temple was built by the tributes and scots of the pious people of the Holy All Savior Ghazanchetsots Church of Shushi, whose construction launched in 1868 – in the days of the kingship of the God-empowered Sovereign Great Emperor of All Russians – Alexander II and under the Patriarchate of Gevorg IV, was completed in 1887 – in the year of the kingship of His Son, Blessed Emperor Alexander III and in the Catholicosate of Markar I in September 20, 1888”) [9] (Fig. 3).

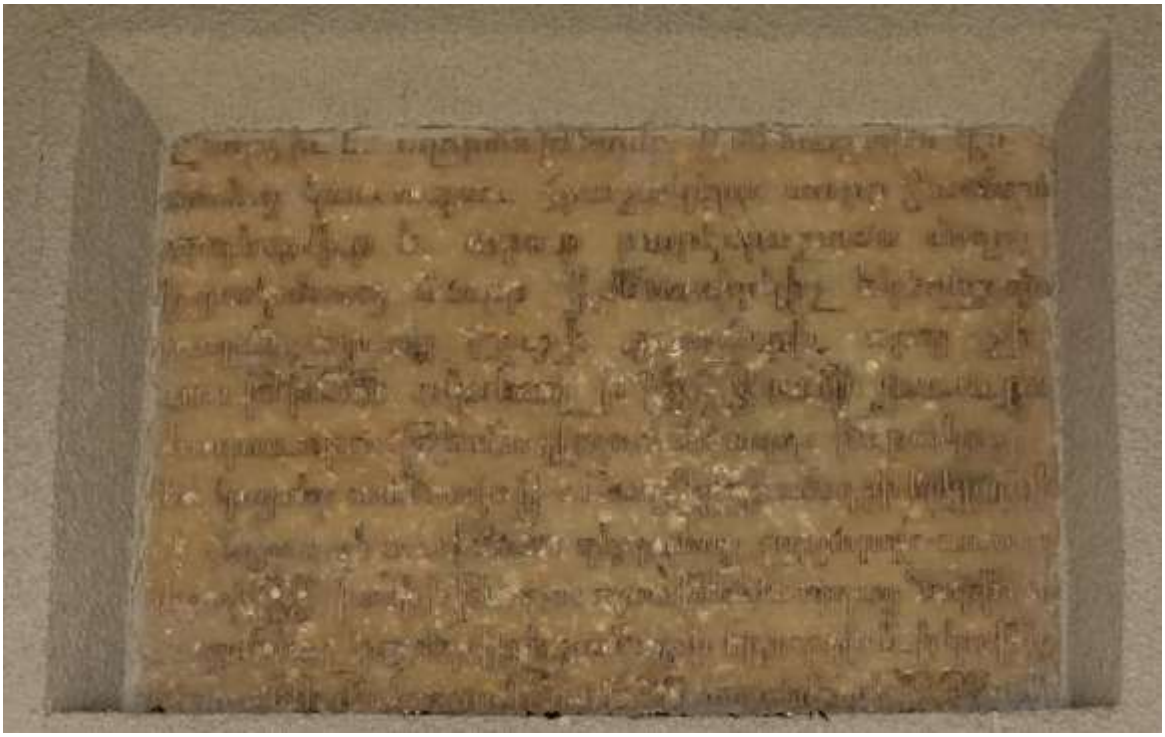


Fig. 3. *The building inscription placed on the southern facade of the church*

Architectural - compositional examination

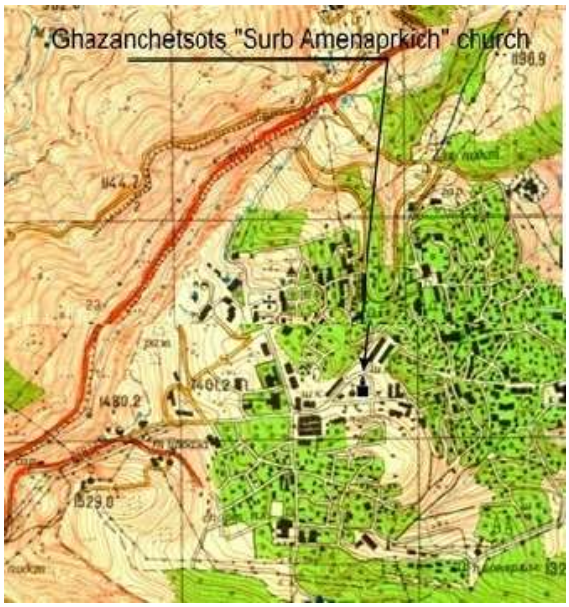


Fig. 4. *Location of the church*

The complex of the Holy All Savior Ghazanchetsots Church is located in the central part of the city, 1378 m above the Karkar valley. Thanks to its elevated location, it dominates the entire plateau (Fig.4). It is the architectural dominant of Shushi city. The church and the belfry are built of finely hewn white limestone (Figs. 5,6).

The Holy All Savior has impressive dimensions (34.7 x 27 x 42 m) and is one of the largest Armenian churches. The four facades of the church with a rectangular plan have externally accentuated apses, which convey cruciformity to the structure (Fig. 7). There are bas-reliefs on the pediments. In the center of the prayer hall, the dome rises on four thick pillars. With its general volumetric solution, the Holy All Savior received a cross-domed composition reminiscent of the Mother Cathedral of Etchmiadzin.

Fig. 5. *The south-western Armenian segment of Shushi and the Holy All Savior Ghazanchetsots Church (1911). Photo: a page from the book by Mkrtchyan Sh., Davtyan Sch., 1997*

Fig. 6. *The Holy All Savior Ghazanchetsots Church of Shushi in the city panorama before the 2020 war. Photo by Hrayr Baze*

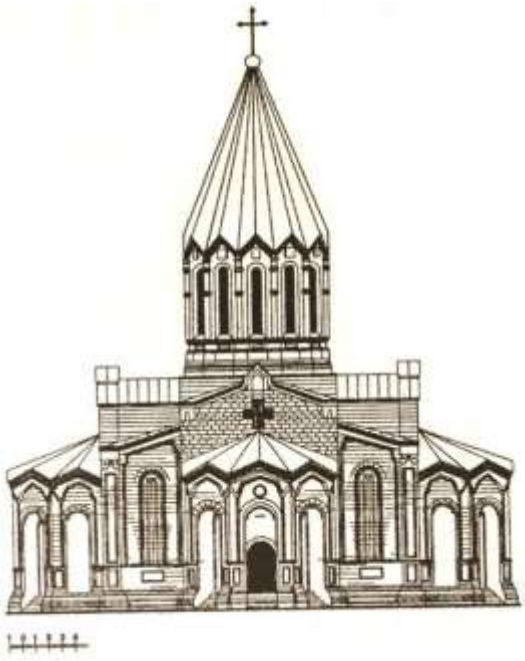
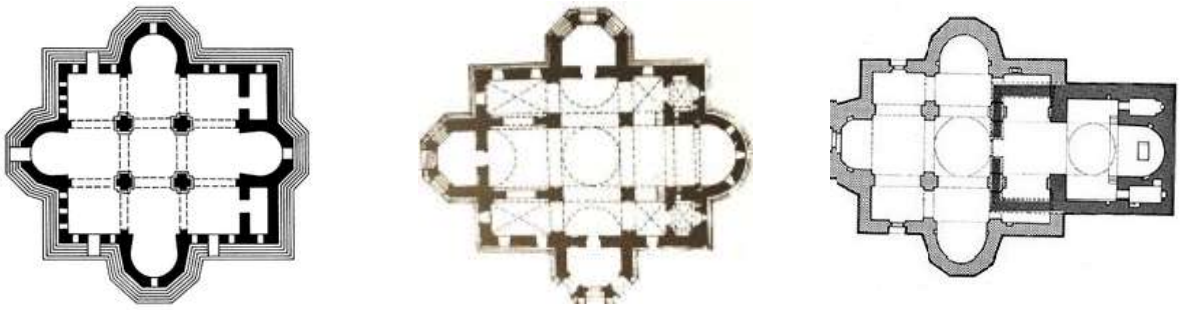


Fig. 7. *The southern facade of the Holy All Savior Ghazanchetsots Church of Shushi. Photo: a page from the book by Mkrtchyan Sh., Davtyan Sch., 1997*

It is similar to the composition of another monument of the XIX century - the main church of the Tade monastery. It is obvious that the architect of the Holy All Savior, Simon Ter-Hakobyan, sought to remain native to the traditions of early Christian Armenian church construction (Fig. 8). The church has three portals that open to the west, south and north. In front of them three-arched semicircle, inwardly and externally multi-faceted nartex-vestibules are built. Originally, there used to be five arches, but the two lateral ones were later lined and closed (perhaps, due to functional purposes). Their existence is one of the features of the Holy All Savior Church of Shushi. Small cruciform windows are opened at the top of the vestibules. The upper parts of the doors are decorated with bas-reliefs included within the frame (Fig. 9).

The external decoration of the church is represented by numerous decorative zones, dimensional portals, window edgings, ornamented arches of doors and windows. Wide and high windows convey upsurge to the volume and abundance of light to the interior.



1 *2* *3*

Fig. 8. *1 - Mother Cathedral of Etchmiadzin, 7th century, 2 - Plan of the Holy All Savior Ghazanchetsots Church of Shushi, 3 - plan of the main church of the Tade monastery*

Fig. 9. *The pediment of the southern vestibule with a bas-relief included within a frame. Photo by L. Kirakosyan*

The dome of the church is also slender, the drum facets are designed in vertical symmetries, with inlined window-niches. The drum is crowned with a fan-shaped spire (Fig. 10). There are numerous Armenian inscriptions on the walls of the church.

Fig. 10. *The dome of the Holy All Savior Church. Photo by L. Kirakosyan*

A three-storey belfry is located a little far away, on the western side of the Holy All Savior Ghazanchetsots Church. The cube-shaped volume of the first floor is accentuated by an east-west axis with a transversal arched opening. In the corners of the upper part of this floor there are four statues of angels blowing trumpets. The faceted walls of the second and third floors of the belfry are joined by wide arched openings. The third floor of the belfry, as in case of a church, is crowned with a fan-shaped spire.

The embellished belt of the belfry is performed with an outstanding craftsmanship. We learn from the extensive inscription on the eastern wall of the building that it was built by Abraham Khandamiryants from Shushi in memory of Gabriel Hovsepyan-Batiryants, who originated from Ghazan and pilgrim Mkrtich Margaryan-Khandamiryants, his wife Balasan, sons of Arup and Stepan, as well as all residents of Ghazan. The date of construction is mentioned at the upper part of the southern wall of the belfry: the summer of 1858 [10]. It is not difficult to notice from this inscription that the belfry had been built earlier than the temple of the Holy All Savior (1868) and that the old church mentioned by Mesrop Taghiadyan, built in the 18th century, used to stand here instead of the current Holy All Savior Ghazanchetsots Church. This is the reason why the belfry stands separately (it is generally accepted that the belfry is built after the church and it is mainly attached to the latter).

The condition before and after the war

The church was closed during the Soviet era. In the 1940s, it was used as a grain warehouse. During the 1950s, the statues of angels at the church entrance were damaged and the dome was destroyed. The Azeris living in the city tore down the hewn roof slabs and the stones of the upper row of the facades and built houses (Fig. 11).

Fig. 11. *The view of the Holy All Savior Ghazanchetsots Church in Shushi from the northwest (1972). Photo: a page from the book by Mkrtchyan Sh., Davtyan Sch., 1997*

In the late 1960s, the church was turned into a parking lot for agricultural machinery. A decade later, barbaric and deliberate explosions and fires were organised inside the church, the epigraphs were effaced. All this has always provoked the protest of the Armenian population. In 1982, the restoration of the Church of All Savior began, which was not going smoothly. According to the restoration master Volodya Babayan, the high leadership of Azerbaijan was hindering the construction of the dome. They realized that after that the church would become dominant not only over Shushi, but also in the vast Karkar valley [11].

During the first Artsakh war, the Azerbaijanis converted the church into a military depot. After the liberation of Shushi, the restoration of the destroyed dome and the whole complex was completed in 1998 (Fig. 12).

Fig. 12. *General view of the Holy All Savior Ghazanchetsots and the bell tower of Shushi from the southwest (after restoration, 1998). Photo by L. Kirakosyan*

On October 8, 2020, the Holy All Savior Ghazanchetsots Church was targeted by the enemy: it was rocketed, the dome of the church and the roofs of the cross-wings were damaged (Fig. 13).

Fig. 13. *The condition of the church after the October 8, 2020 missile attack* [5]

Immediately after the end of the war official Azerbaijan announced that the historic districts of the city, mosques and churches in Shushi will be restored, in its media emphasizing especially the restoration of the churches as an indicator of religious, national solidarity. It is noteworthy that almost all the delegations arriving in Shushi, the representatives of the organizations were shown the "restoration" of Ghazanchetsots, which would gain "its original appearance", and which, according to the Azerbaijanis, was not Armenian. The Azeri media presents Gazanchetsots "Surb Amenaprkich" church, sometimes as an Orthodox, sometimes as an Udian church, which "the Armenians Armenianized that by transforming the dome after the occupation of the city"[6]

According to the website "monument watch.org" before the visit of Ilham Aliyev and his wife in early January 2021, only some "renovation" work was done inside the temple.

The Azerbaijani side, after its double shelling, removed the pile of stones inside the temple, collapsed walls, scaffolding was erected around the temple, the church dome was removed, which thereby distorted the appearance of the temple, the inscriptions written with paint were removed. It can be seen that the green construction netting is frayed, and the part of the roof that collapsed after the shelling of the southern wing has not been restored, not even covered, the rest of the ceiling is in disrepair (Fig. 14).

Fig. 14. *General view of the of the Holy All Savior Ghazanchetsots Church in Shushi as of 1921*

[5] Photo source: meganewes.am/assets/uploads/ 7vu8puzzo7ftn596c1mz1605464215

[6] https://www.youtube.com/watch?v=iHiIZjQh2E4.

It can also be stated that the fence of the temple courtyard was destroyed, the gates, khachkars that were standing in the courtyard were displaced.

In a video shared on Telegram-channel of the Armenian Military Portal on May 22, 2022, it is seen that a fairly dense grass cover has grown in some parts of the roof, the damage and collapse have not been eliminated and the entire area around the temple is in a state of disrepair (Fig. 15) .

Fig. 15. *The dome of the church of Gazanchetsots "Surb Amenaprkich" in Shushi* [7]

This practice is typical for Azerbaijan's "policy of cultural preservation". The same was done with the early Christian church of Vankasar [12-17]. In Baku, they claim that, allegedly, the temple originally looked like this before it was "Armenianized by the Armenians".

Conclusion

The bibliographic and original research of the temple of the Holy All Savior of Shushi showed that:

- The church was built according to the preliminary order and developed project, in accordance with the traditions of the Armenian medieval church architecture.
- The orderer of the church was the Armenian community of Shushi represented by the residents, so called “ghazanchees”.
- It refers to the cross-domed structural type, which became widespread in the Armenian architecture of the 6th-14th centuries AD.
- Both during the Soviet period and during the Artsakh wars, the Holy All Savior Ghazanchetsots was attacked and destroyed by the Azerbaijani authorities, which are qualified as manifestations of cultural vandalism.
- Currently, Azerbaijan, denying the previous restoration of the Holy All Savior Ghazanchetsots of Shushi, ignoring and distorting all the facts proving its Armenianness, is reconstructing the structure, passing it off as a Russian Orthodox church.
- The popularization the Holy All Savior Ghazanchetsots of Shushi is a way to draw the attention of international organizations for the preservation of monuments to the false policy of "cultural preservation" of Azerbaijan, trying to protect the building from further falsifications.

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[7] Photo source: https://t.me/military_arm/13434?single&fbclid=IwAR0IYpXzM09vjsMasjj_Gwy1kqtpfwkYq4cxPJ5Dp4yK6N35xfiXlzIDGMU

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MONITORING OF WEAK AND MODERATE EARTHQUAKES USING GNSS TECHNOLOGIES

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Abstract: *The geodetic monitoring results of the earthquake in the seismically active areas of the Republic of Armenia using GNSS technologies are presented. The necessity of using geodetic tools-equipment, in particular satellite technologies, in the process of seismic studies is substantiated, proving the fact of the validity and reliability of the data. The monitoring results of the horizontal-vertical shifts' coordinates of the permanent reference stations affected by the earthquake in Armenia on February 13, 2021 at different time intervals (5 days before the earthquake, 2 hours and 10 minutes before and after, as well as at the moment of the earthquake) were analyzed and the graph analyzes were given. The results show that it is possible to mark the time of earthquake registration by means of coordinates recorded at a frequency of 1s, and as a result of the earthquake, it is possible to monitor the Earth's crust displacement vectors at certain intervals through reference stations, recording the directions of horizontal and vertical displacement of the Earth's crust. At the same time, locating reference stations on hard rock will provide an opportunity to have a more accurate database, which will contribute to the development of geodetic monitoring in seismically active areas using GNSS technologies.*

Keywords: *Permanent reference stations, GNSS technologies, deformation, geodynamics, earthquake.*

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Introduction

The idea of using the potential of Global Navigation Satellite Systems (GNSS) in seismology was first discussed back in 1990. Measurements made through GNSS during the earthquake were studied, the results of seismic observations of earthquakes were described to measure large movements in a short period of time. The materials used for GNSS seismology, which are classified as high-class data, can be analyzed using the same models obtained for daily average position analysis. The difference between traditional geodetic surveys and high-frequency global navigation satellite systems is the function assessments. For most geophysical problems, the location of the point is determined once a day, and in the case of seismic applications, it can (and should) be done every second, considering that modern equipment has this capability [1,2].

We have reviewed the results of some international analyzes based on data from GNSS stations located in earthquake-prone areas [3,4,5]. GNSS's ability to detect seismic shocks was far greater than experts expected. Nowadays GNSS has been improved, there are analytical methods available to optimally measure GNSS seismic shifts, and we need to work with different professionals to use the obtained data more efficient.

Thus, high-class GNSS data has an invaluable role in excluding general analysis errors and distinguishing pre-seismic and post-seismic faults (deformations) during strong earthquakes. The use of GNSS geodetic data by seismologists in earthquake surveys can be done through GPS waves archiving. It should be noted that not all earthquake cracking are superficial, and not all GNSS receivers can be located in the direction of ruptures [6].

Studies allow to insist that the further work of GNSS seismology should develop the proposition that GNSS could be used to study the effects of large (strong) displacements, large-scale movements of the Earth's surface, and the engineering structures of that motion [2,6,7].

Materials and Methods

Data collection by thousands of GPS receivers around the world continues to be carried out regularly, collecting 1 Hz GNSS data. The data obtained are sufficient for earthquake studies, but they can be more valuable for earthquake studies if the receivers sample data at a higher frequency. However, higher frequency measurements also have their drawbacks, as high-frequency data collection poses overloading during remote sensing and archiving. This system is an important component of the study of multifactorial phenomena of modern geodynamics, due to changes in the combinations of spatial-temporal, natural-man-made, endogenous and exogenous influences, which leads to a situation where a sensitive instrument (method) measuring modern geodynamic processes becomes more effective not only by recording a useful signal but also by detecting malfunctions [8,9,10,11].

It should be noted that surface surveying methods, despite the laboriousness of fieldwork, are simple and easy to develop. In contrast, satellite observations are easier to measure, but much more complex in the development process, which can lead to significant distortions in the final assessment of the geodynamic state.

For large areas, according to GNSS measurements, the horizontal component of the Earth's surface was more than the vertical height. The technological properties of geodetic observations allow to measure the vertical component much more accurately by alignment, and the horizontal component by satellite. Hence, it is impossible to make a principled conclusion with the same measurements performed in combination, as each method has the degree of accuracy of the analysis of its measurement results. However, behind the basics of measurement theory is that the identification values of observation results should not depend on the measurement method. Otherwise, the conclusion of predominant vertical or horizontal displacements in the general course of the geodynamic process will reflect the level of technological capability of this or that measurement method.

GNSS measurement methods have a completely different way of receiving a signal, a separate methodology of point monitoring and signal processing in contrast to other new generation equipment. Regarding the problems of modern geodynamics, it is possible to point out two main difficulties in using the results of satellite geodesy observations. First, the vast majority of studies focus on the horizontal displacement component of the coordinate system. The second, the observation network has a lower density than the geodetic networks used in traditional measurement methods, which reduces their ability to study seismic processes in local areas. Thus, in order to make a comprehensive analysis, it is necessary to combine the traditional methods and satellite geodetic measurements data and to develop a single platform.

To solve these problems, a number of scientific studies are currently being carried out, comparing the accuracy of coordinate determination obtained by GLONASS and GPS systems, as well as comparisons between the results of observations of the use of traditional and geodetic satellite systems are carried out.These studies have shown that the GLONASS system has almost the same efficiency as GPS so the two systems can be used together in research. However, studies of traditional satellite measurements show that the average annual horizontal velocity, determined in two ways by separate analysis of the data obtained, differs to a certain extent. Therefore, there is a need for targeted studies to analyze the results of geodetic satellite and surface traditional surveys, combining them with spatial-observation systems, in order to properly identify deformations [12].

The coordinate basis for the study and detection of vertical and horizontal displacements of Earth's crust in the areas of active seismic ruptures in the territory of the Republic of Armenia are the main points of the RA National Geodetic 0, 1st and 2nd class nets, the pillars and stamps of the RA State Elevation Network, as well as the net of 12 permanent reference stations established in the Republic of Armenia in 2013. The permanent reference stations net (Akhuryan, Alaverdi, Aparan, Armavir, Artashat, Gavar, Ijevan, Khndzoresk,

Meghri, Sisian, Vardenis, Yeghegnadzor) is distributed throughout the territory of the republic at a distance of about 70km[1].

Special polygons have been set up in some earthquake-prone areas of the Republic of Armenia to study Earth's crust movements. Based on accurate geodetic measurements in seismic zones, vertical-horizontal displacements can be calculated, according to which it is possible to detect regions of deformations, which in turn will lead to improved earthquake prediction.

Results and Discussion

We carried out certain researches in the Republic of Armenia by studying the earthquake that took place in Yerevan on February 13, 2021 at 3:29 pm (Yerevan time), to make the efficiency of the geodetic method more obvious using GNSS technologies, to record the moment of the earthquake, as well as to characterize the dynamics of horizontal and vertical movements of stations some time before and after the earthquake. The epicenter was reported 8km southeast of Yerevan, at 44.54 degrees east longitude and 40.11 degrees north latitude, with a depth of 10 km. According to the data of Territorial Service of Seismic Protection of RA MES, M=4.7, the strength of the underground shock in the epicentral zone was 6-7 points. Receiving and observing the diagrams based on the coordinate changes obtained in 2 hours, 10 minutes and 1 sec. intervals on February 13 at 3:29 pm at Armavir Permanent Reference Station near Yerevan, it is obvious that the deviation is especially significant when comparing latitude and ellipsoidal height coordinates. The station is located in the middle of a 3-story building roof in Armavir city. The geological structure of the site includes upper Pliocene and Pleistocene basalts, tuffs and tufa-breccias, which are placed in the form of overlays and flow on the tertiary sedimentary layers and covered by younger alluvial-proluvial-deluvial sediments.

The two-hour long-distance diagram shows a slightly downward-pointing wave, which reached its lowest point at 44.03963 at 11:30 am, then observed an increase in longitude coordinates until the earthquake at 3:29 pm. This increase continues until the end of the presented observation at 11:29 pm at which point the curve reaches 44.03965 east longitude, twenty times higher than the 44.039645 marked 5:30 am at the beginning of our observation. Interestingly, the longitudinal coordinate index recorded its lowest value 4 hours before the earthquake at 11:30 am (Fig. 1).

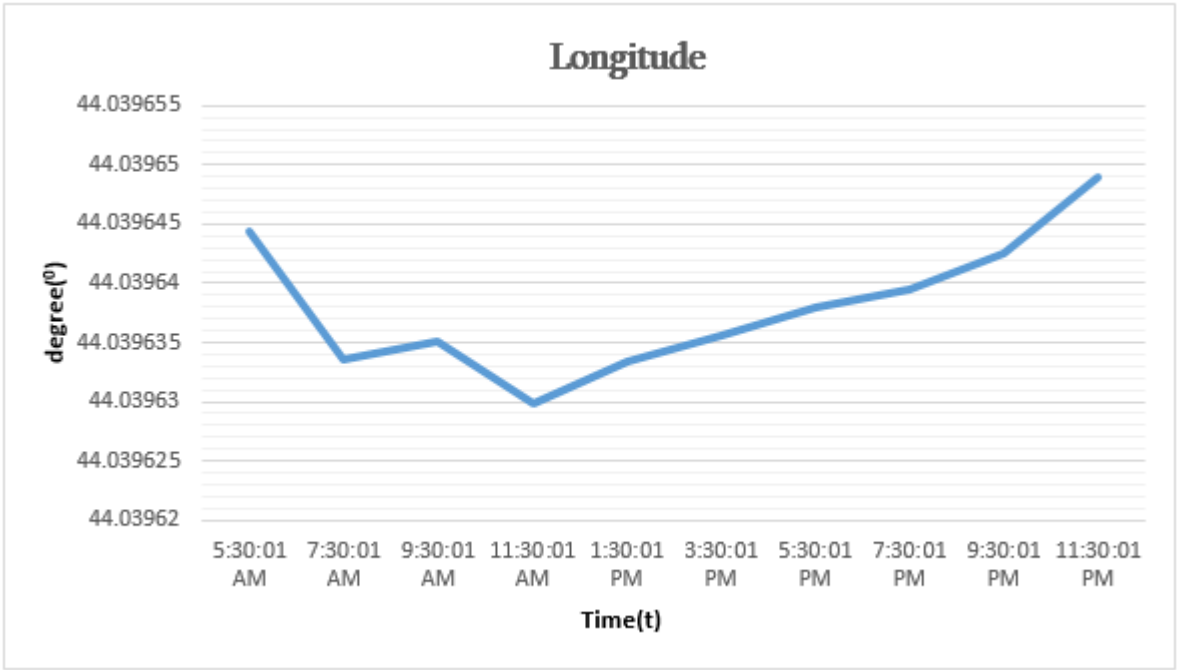

Fig. 1. *The longitude coordinates of Armavir permanent reference station on February 13 at 3:29 pm (Yerevan time)*

[1] http://www.euref.eu/TWG/EUREF%20TWG%20minutes/35-Bratislava2004/TWG-Bratislava-topic-02.pdf

We already have another image in the graphic diagram obtained by placing the latitude coordinates in 18 hours at the same time interval of two hours (Fig. 2). Here, from 40.15557544 degrees north latitude, we have a sharp increase in the curve from 7:30 am to 9:30 am. For the next 2 hours until 11:30 am the latitude coordinates are stored with a slight difference, and then until 1:30 pm a return to the morning data is registered. By the time of the earthquake, at 3:29 pm, we have a sharp rise in the curve again, which continues until 5:30 pm. After 5:30 pm, a slight decline of the curve is observed again.

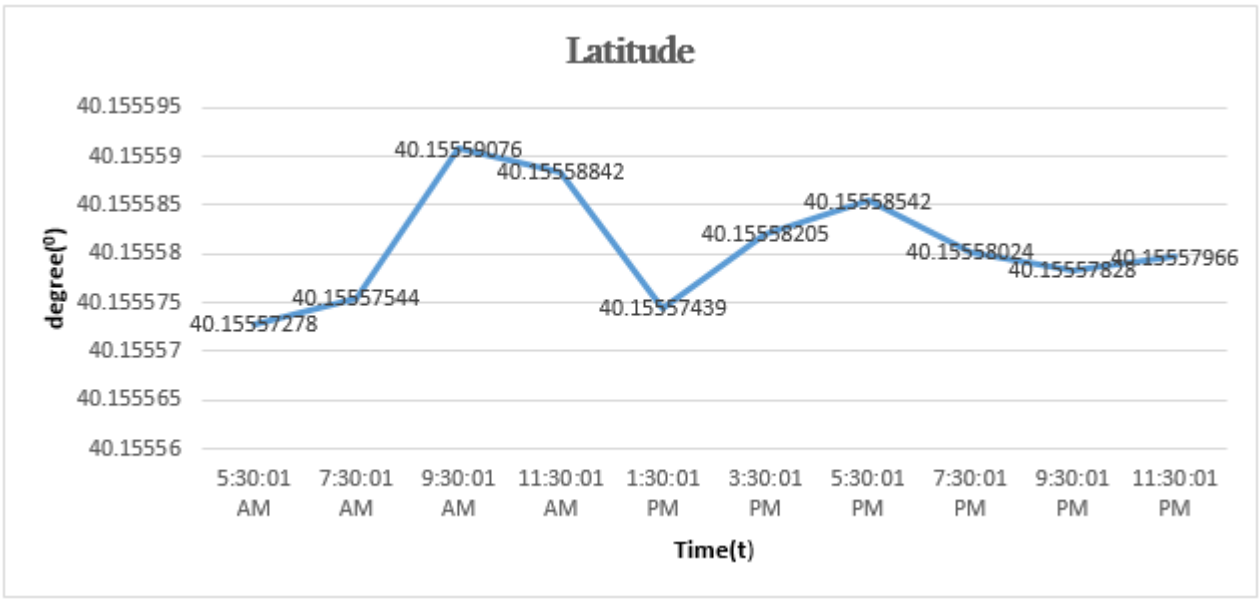

Fig. 2. *The latitude coordinates of Armavir permanent reference station on February 13 at 3:29 pm (Yerevan time*)

Thus, from 7:30 am, the latitude coordinates shifted in ascending order, at 1:30 pm returned to almost the same degree, then from 1:30 pm until the moment of the earthquake, and 2 hours after that the latitude coordinates increased. We could see another image in the diagram showing the coordinate displacements of the ellipsoidal height (Fig. 3).

Here at 5:30 am we have an altitude of 904.6041983m, which is almost unchanged for 4 hours until 9:30 am. Then, until 11:30 am, we have a sharp drop to 901.5548945m. In the following 10 hours, from 11:30 am to 9:30 pm, the height coordinates increase again, and from 9:30 pm, the height begins to decrease, reaching a figure slightly different from the initial observation height - 903.6532062.

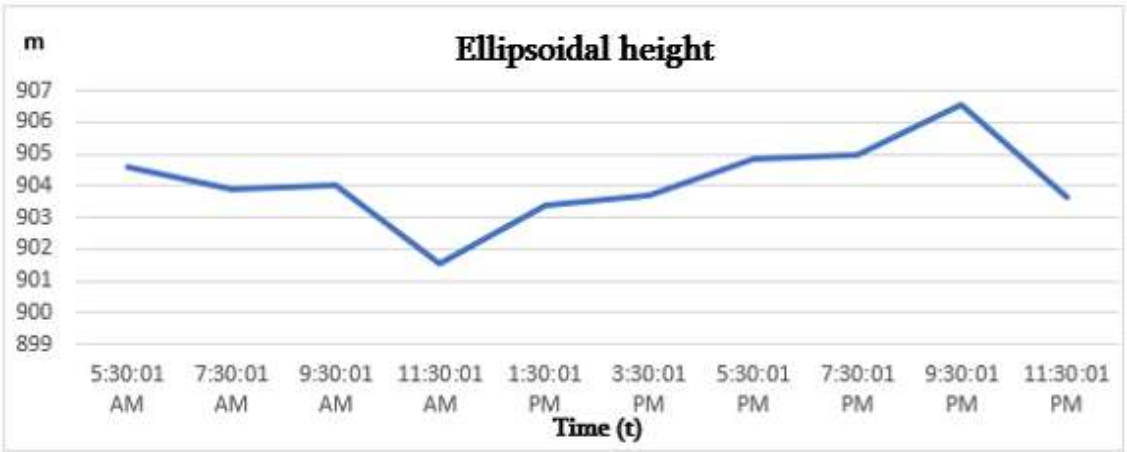

Fig. 3. *Ellipsoidal height coordinates of Armavir permanent reference station on February 13 at 3:29 pm (Yerevan time)*

After comparing the coordinates of Armavir permanent reference station in 2013 with the coordinates of the February earthquake registered on 03.29.2021 at 3:29 pm, we came to the conclusion that the coordinates are significantly deviated. The initial coordinates of the station are:

Latitude - 40.155576989,

Longitude - 44.039635743,

Height - 906.4403.

Let's compare with the coordinates registered at 3:29 pm on 13.02.2021

Latitude - 40.15558205,

Longitude – 44.039635,

height – 903.7192717.

The deviation is especially significant when comparing latitude and ellipsoidal height coordinates. It can be concluded that the effect of earthquakes due to the discharge of energy accumulations in a certain mass of the Earth's crust during the pre-earthquake period is obvious in the process of determining the coordinates of permanent reference stations. If we take into account the fact that the Republic of Armenia is in the zone of seismic activity, the significant deviations of the coordinate data of the stations can clearly help in the study of horizontal and vertical movements of the Earth's crust.

Next, at 10 minutes intervals, we have a slightly different image in the coordinate diagram. As a result of joining the longitude coordinates, we have already obtained an upward curve, which reached its highest point 44.03964397 at 3:00 pm, and at the time of the earthquake, at 3:29 pm, we already have a decrease in the eastern longitude 44.0396368 degree. It is important, that in the 10 minutes interval diagram of earthquake (in two hours before and after earthquake), we observed visible "abrupt fluctuation", that means, we have a sharply upward curve. In the two hour interval diagram from 1:30 pm to 5:29 pm there is a sloping, slightly straight section tending upwards, which has no sharp rises or fluctuations. At the first moment of the monitoring, at 1:30 pm, longitude 44.03962802 was marked, and at the last point of the chart 44.03963767, at 5:20 pm These data are especially visible in the following diagram, where the detailed coordinate data are recorded in more detail (Fig. 4).

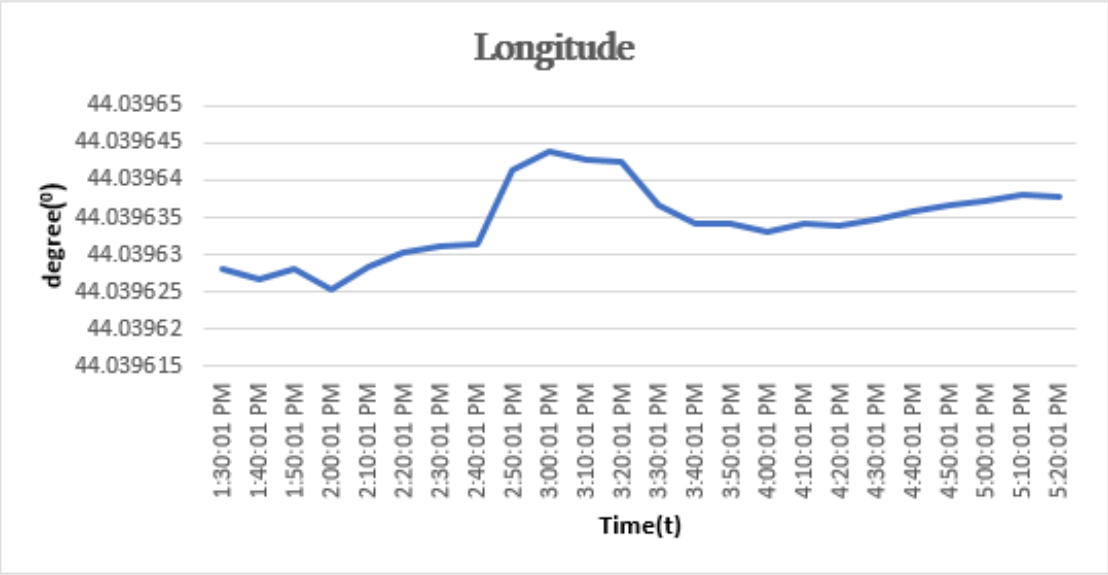

Fig. 4. *Graphs of longitude coordinates in 10 minutes intervals*

As a result of observation with 10 minutes intervals corresponding to latitude for 3 hours 50 minutes, we have a downward curve in the graph-diagram obtained by connecting 24 points, the minimum value of which was registered 9 minutes before the earthquake, at 3:20 pm. 40.15557923 degrees north latitude was registered

at the starting point of the monitoring at 1:30 pm and at the end, at 5:20 pm, we have registered 40.1555851 degrees. If we try to move the chart to the corresponding part of the graph with a two-hour interval depicting our latitude, then we will see that here we have not a slightly deviated image, but a significantly different one, from 1:30 pm to 5:20 pm the graphic curve has not a decrease, but an increase (Fig.5).

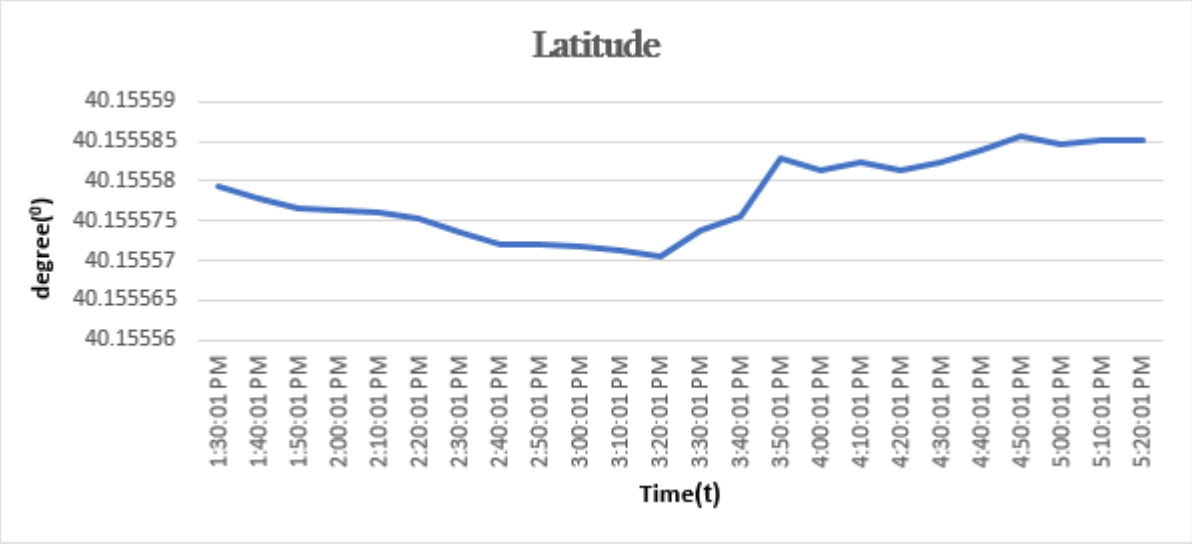

Fig. 5. *Graphs of latitude coordinate in 10 minutes intervals*

The discrepancy in the ellipsoidal height data is very insignificant, as there is almost no radical difference in the direction of the curve. While at the initial moment of the earthquake in our graph with two-hour intervals the ellipsoidal height was 903.7192717 (Fig. 6).

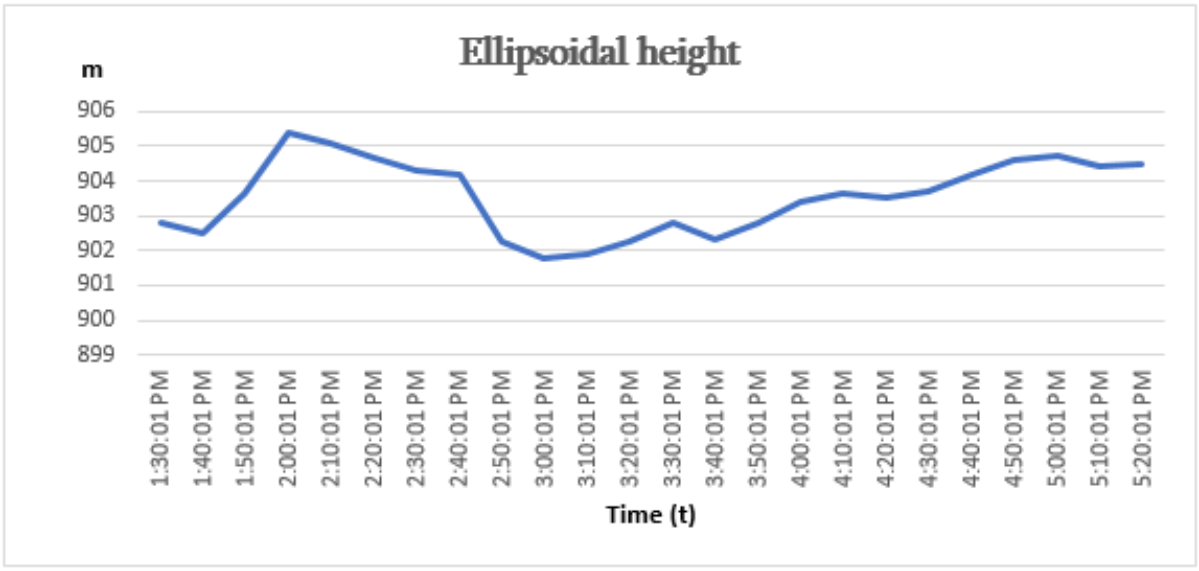

Fig. 6. *Graphs of ellipsoidal heights in 10 minutes intervals*

If we take into account the fact that the Republic of Armenia is in the zone of seismic activity, the significant deviations between the values of the coordinate data of the stations can clearly help in the study of horizontal and vertical movements of the Earth's crust.

Analyzing the graphs obtained with the interval of seconds during the earthquake registered at 3:29 pm, an obvious shift was recorded in all three components, which may indicate that the GNSS stations are reliable for recording earthquakes (Fig.7).

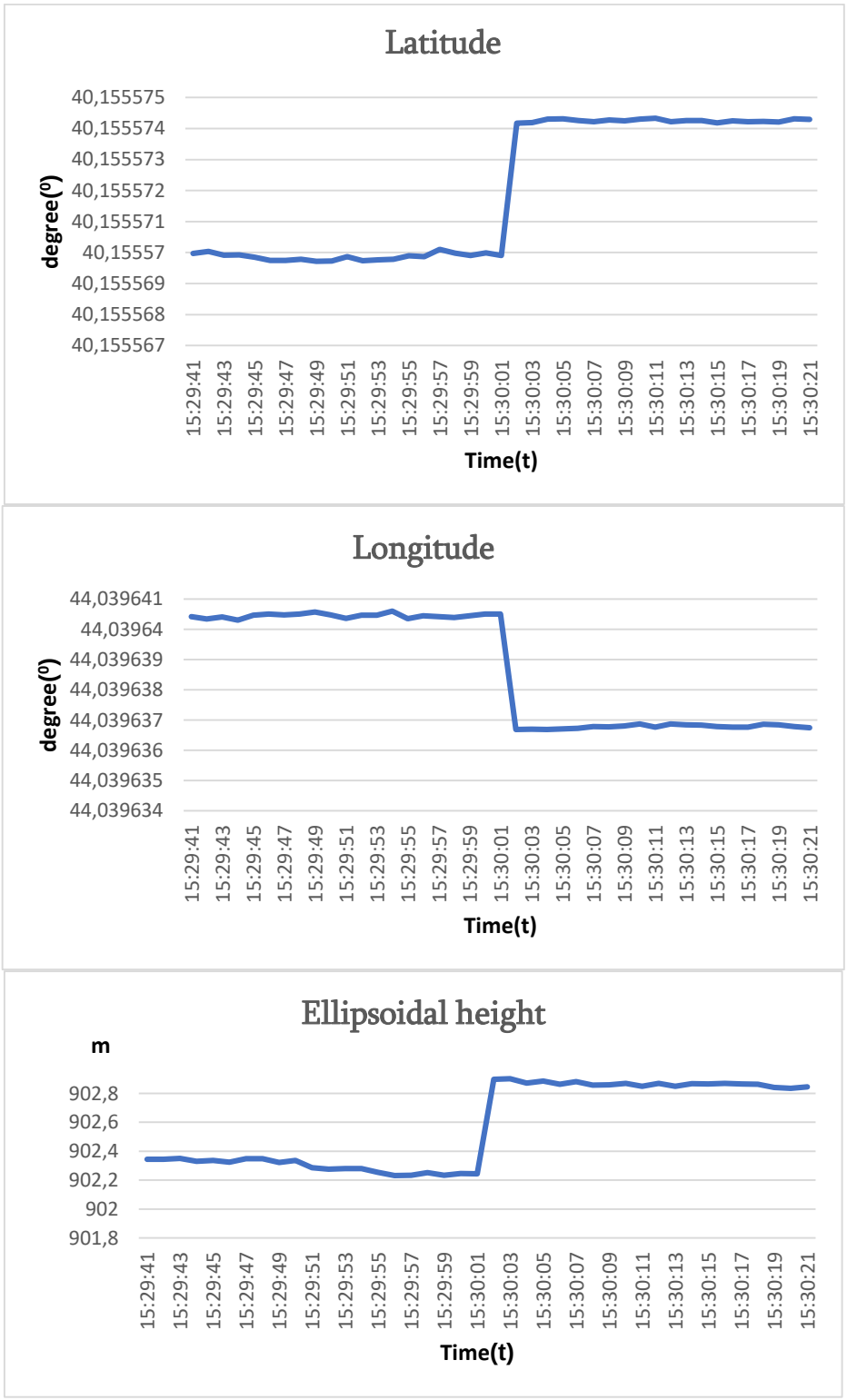

Fig. 7. *Analysis of data every 1 second of measurements*

Once again, to make sure that GNSS stations can get a realistic picture of the Earth's crust horizontal and vertical movements, the analysis of the difference in the balanced data of the same stations was carried out 5 days before and after the earthquake by the 9 reference stations coordinates of the RA Cadastre Committee, according to which no change was registered in the APAR reference station with Y and Z components, and 1mm shift was registered in the X component, changes in the ARMAV station are 3mm shift in the X direction, no shift in the Y direction, and a decrease of 1mm in the Z direction (Fig.8).

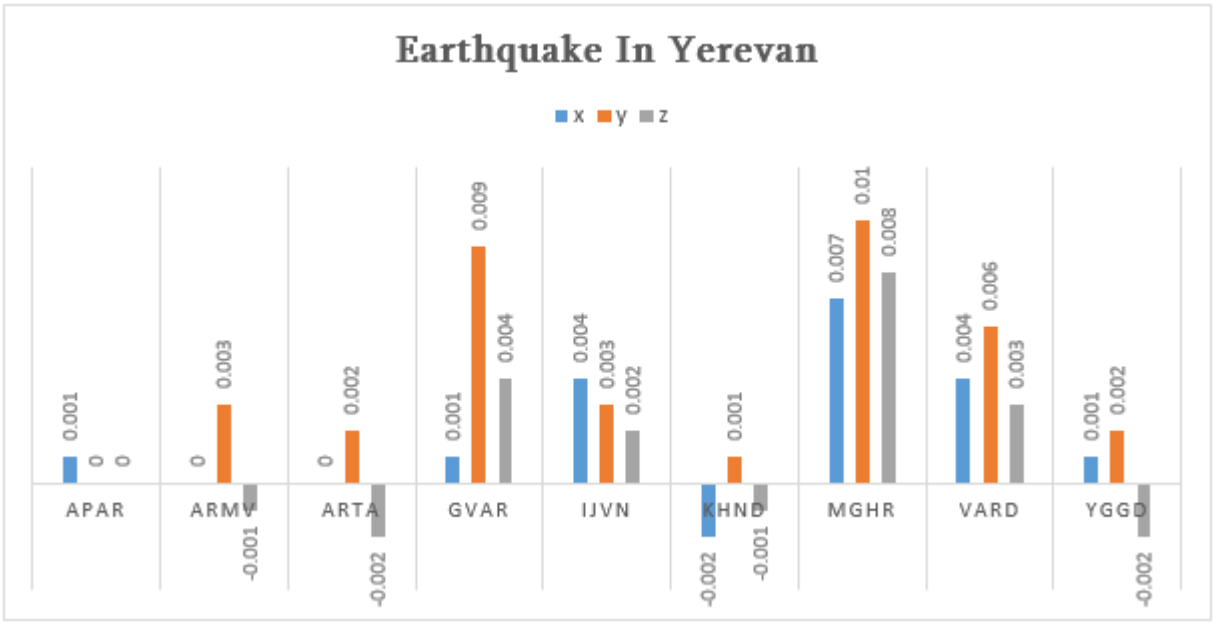

Fig. 8. *Analysis of monitoring 9 stations data for the periods of 08.02-12.02.2021 and 14.02-18.02.2021 (m)*

Summarizing the above, we can state that the 9 permanent reference stations net at the horizontal component moved in the northeast direction after the earthquake, and in the vertical component of the stations there is an increase, which once again proves that the data obtained through monitoring by GNSS stations are consistent. According to international studies, the displacement of the Arab-Eurasian plate area corresponds to the north-eastern direction, which is explained by the convergence of the Arabian plate to the Eurasian plate (Fig. 9).

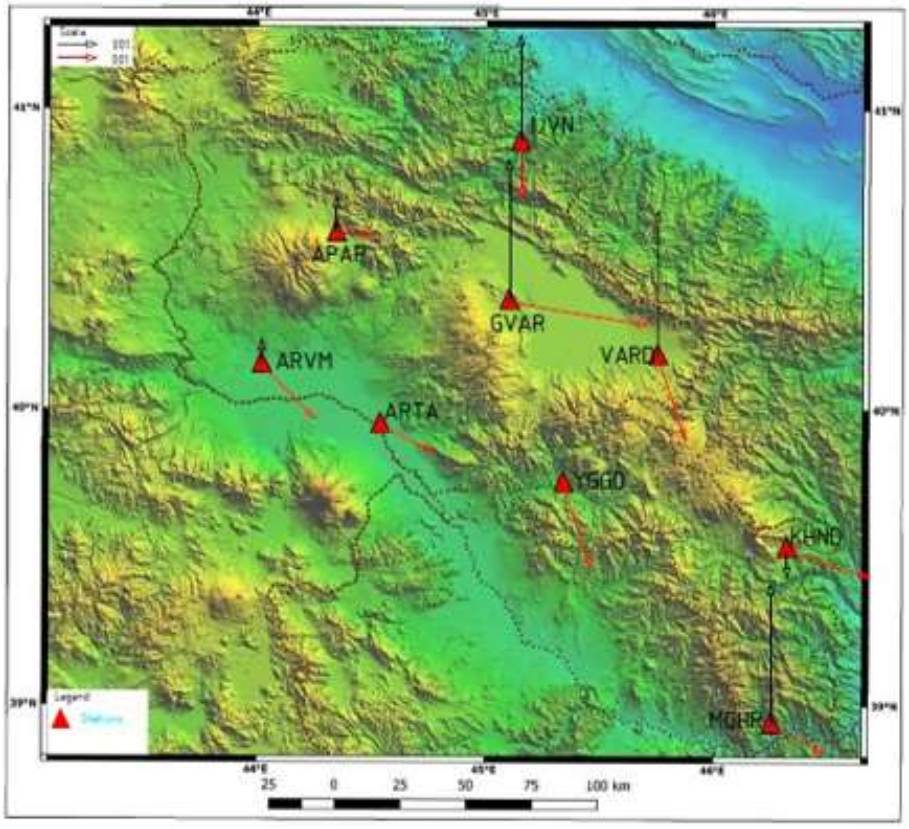

Fig. 9. *Analysis of permanent reference net data*

Conclusion

It can be concluded that the effect of earthquakes due to the discharge of energy accumulations in a certain mass of the Earth's crust during the pre-earthquake period is obvious in the process of determining the coordinates of permanent reference stations. On the basis of which the values of the horizontal and vertical shifts of the permanent reference stations due to the earthquake of February 13, 2021 in Armenia were analyzed and their graphs have been made.

Thus, the monitoring of the earthquake in Yerevan on 13.02.2021 by means of reference stations shows that it is possible to mark the time of earthquake registration by means of coordinates recorded at a frequency of 1 sec., and as a result of the earthquake, it is possible to monitor the Earth's crust displacement vectors at certain intervals through reference stations, recording the directions of horizontal and vertical displacement of the Earth's crust. At the same time, it should be noted that these reference stations are located on the roofs of buildings, and with our network of 18 complex reference stations, some of which will be located on hard rock, it will be possible to have a more accurate database which will contribute to the development of geodetic monitoring in seismically active areas using GNSS technologies.

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STUDY OF LINEAR DEFORMATION CHANGES IN HEAVY CONCRETE BASED ON MODIFIED PORTLAND CEMENT

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Abstract: *The investigation results revealed how modified standard Portland cement of grade 42.5 (M400) with 10% of the expanding additive changes the linear deformation characteristics of heavy concrete. Heavy concrete of class B 22.5 (M300) with a different water-cement ratio (slump 3 cm and 5 cm) was selected as the object of study, from which cubic specimens of side 10 cm were prepared. The impact of modified cement on concrete linear deformations is determined at the ages of 1, 3 and 28 days under normal setting conditions, and changes in the sizes of the same specimens are checked for three months under air-drying conditions. The study confirmed that the most effective impact of modified cement, as in the case of construction mortars, is also observed in 3-7 days of curing. It was found that the effect of modified cement is increased with the increase in the water-cement ratio, and a relatively low percentage of expansion through the low water-cement ratio is explained by the certain rigidity of the concrete internal structure.*

Keywords: *modified Portland cement, expanding additive, heavy concrete, water-cement ratio, linear deformations.*

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Introduction

Ordinary Portland cement has many favorable properties. In certain cases, depending on the importance of the designed structures, buildings, and operating conditions, their use becomes impractical as shrinkage is observed during curing processes. As a result, it becomes imperative to use new types of binders. In particular, to ensure the structure's joint leakproofness and to decrease the water permeability of the hydraulic structures, it is crucial to use non-shrinkable, expanding concrete. For concrete production, special types of cement have been developed in different countries, which, unlike ordinary Portland cement reinforcement, do not exhibit shrinkage but, in contrast, expand and contribute to the production of non-shrinkable expanding construction mortars and concrete. The paper is about the effect of a special expanding admixture previously developed based on local raw materials, on the linear dimensions of heavy concrete.

Materials and Methods

The object of the study is a heavy concrete class 22.5 (M300) made of different water-cement ratios with a slump of 3cm and 5cm. Specimens were stored under humid conditions for up to 28 days, after which they were stored in air-drying conditions for up to 3 months. The impact of modified cement on the change in linear dimensions of heavy concrete specimens is determined by an indicator with an accuracy of 0.001mm. The study data are presented in Tables 1 and 2.

Table 1. Concrete linear dimension changes with a slump of 3 cm

Linear dimension change,%				
Concrete setting time				
1 day	*3 days*	*7 days*	*28 days*	*3 months*
0.11	0.22	0.35	0.30	0.29
0.11	0.19	0.37	0.32	0.32
0.12	0.20	0.36	0.31	0.31
Average				
0.11	0.20	0.36	0.31	0.31

Table 2. Concrete linear dimension changes with a slump of 5 cm

Linear dimension change,%				
Concrete setting time				
1 day	*3 days*	*7 days*	*28 days*	*3 months*
0.11	0.22	0.40	0.36	0.34
0.10	0.25	0.40	0.32	0.36
0.12	0.22	0.45	0.40	0.36
Average				
0.11	0.22	0.42	0.36	0.35

Main Part

Through examining the work of I.V. Kravchenko, T.V. Kuznetsova, B.E. Yudovich, T.G. Gabadadze, and other scientists, it has been determined that lime and sulfate-containing components are the expanding materials during special-type cement production [1–9]. We have determined that the most practical and affordable method to produce special cement is the synthesis of specific expanding additives and the chemical activation of Portland cement by this additive. This conclusion is based on the authors' studies and considers the possibilities of the raw material base of the Republic of Armenia. We have studied the natural minerals and various industrial wastes of the republic. We concluded that the carbonate-containing additive could be the smoke released from the flue gases removed from the furnaces of the Ararat cement plant. The sulfate-containing component is the gypsum of Tokmahgol or Parakar mines. The raw material calculations confirmed that, it would be better to use the Parakar gypsum as a sulfate-containing component, as the use of the latter increases the content of 3(CA) $CaSO_4$, the main mineral that promotes the expansion of the synthesized additive. For the synthesis of additives based on the abovementioned components, raw materials of different percentages were prepared and kiln roasted at temperatures of 900–1100 °C. Physical-chemical studies of the produced sintered material confirm that the highest quantity of the expanding mixture is observed at a weight ratio of 40:60 cement powder-gypsum, which was introduced in various amounts into the 42.5 grade cement of the Ararat cement plant. The effect of the additives' introduction of different quantities into this composition, which expanded the cement-construction mortar, has been tested. It has been shown that a higher expansion is observed with the addition of 10% additive [10,11].

Based on the aforementioned characteristics, it was investigated how modified cement in the same quantity affected changes in the linear deformations of heavy concrete.

Discussion of Results

The data study in the tables reveals that the higher water-to-cement ratio in the concrete mix enables the concrete to expand proportionally more than it would with a lower water-to-cement ratio. This phenomenon can be explained that concrete has a more rigid internal structure under a low water-to-cement ratio.

Conclusion

Analyzing the data of heavy concrete sample linear change under different ages, which are modified with the developed additives, the expansion phenomenon depends not only on the additive quantities but also on the water-cement ratio of the concrete mix. Concrete expansion has been shown most effective when using modified cement between the ages of 3 and 7 days after setting. Besides, increasing the value of the water-cement ratio of the concrete mix contributes to a relative increase in the percentage of concrete expansion. We have established that during the later set-up period, i.e., up to 3 months in ventilated conditions, the specimens practically do not change their linear dimensions.

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STUDY OF ENERGY DISSIPATION IN A TWO-PHASE SOIL SYSTEM

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Abstract: *The dependence of energy dissipation coefficient on filtration properties and on creep characteristics of soil skeleton is examined. The study was carried out on the basis of the general solution of the joint task of creep and consolidation theory for a two-phase soil system obtained on the basis of the generalized model of bulk forces, taking into account the interaction of soil phases, changes over time in the general stress state at any point of the soil and additional pressures in pore water, and incomplete transfer of external pressure to the pore water. Interactions between phases are taken into account in the solution of the one-dimensional joint task of the theory of creep and consolidation, and the creep kernel is taken in the form of an exponential function. The formula for the deformation of two-phase soils is presented as the sum of two syllables due to primary and secondary consolidation of the soil. The strain formula uses experimentally obtained values of filtration characteristics and creep parameters of the soil skeleton. Using the formulas obtained, hysteresis loops under sinusoidal stress changes can be plotted and the energy expended per deformation cycle and the dissipation coefficient for two-phase soil can be obtained.*

Keywords: *consolidation, creep, two-phase soil, hysteresis, dissipation.*

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Introduction

It is known that under repeated stresses of a material there is a phenomenon of hysteresis, which is determined by energy dissipation. An immense number of works are dedicated to the study of the hysteresis phenomenon [8-11]. The mechanisms generating hysteresis are extremely diverse for different materials and test conditions, although in any case they are determined by rheological processes.

In many works [4-7], when studying the dissipation of mechanical energy and damping of natural vibrations, an attempt is made to find a relationship between energy dissipation and the parameters of material characteristics. The work [4] shows that the energy dissipation in the ground from cycle to cycle changes significantly, and the loading parameters strongly affect the value of the absorption coefficient. In this work [5], based on the data on the creep of the ground when using the theory of aging and heredity, hysteresis loops were drawn and compared with the experimental data for low-cycle creep, and it was found on the example of soils that the theory of heredity, in general, can be recommended for describing the absorption of energy. In this work [6], the dependence of the absorption coefficient on the period of cyclic loading, the degree of cycle asymmetry and on the cycle number for a material deforming according to the linear heredity theory is analyzed. The reviewed works do not take into account the structural peculiarities of materials with which the formation of the deformation and dissipative properties of materials is conditioned. Materials with pronounced structural features can be considered to be primarily two-phase (water-saturated) soils whose compaction under load is due to the process of water filtration from the soil pores and simultaneously to the creep of the soil skeleton [12,13].

In this work [14-17], the tasks of determining pore pressure in water-saturated soil under cyclic loading under conditions of absence of drainage were considered. Such a formulation and solution of the tasks was due to the fact that under short-term cyclic impacts pore pressure does not have time to dissipate and essentially the consolidation process does not begin. At the same time, it is obvious that there are conditions when cyclic

impacts may be prolonged and at small filtration coefficients the consolidation process may develop over time. In this research [20] the one-dimensional task of consolidation of a water-saturated soil layer under an additional cyclic load was considered, assuming that the pore water contains air, in dissolved form and as bubbles, and the soil skeleton has rheological properties described by the equation of the modified Maxwell model.

What are the features of the consolidation process of water-saturated soil under alternating loads?

When the load is removed or, similarly, when additional negative load is applied, the process of swelling-reconsolidation of water-saturated soil occurs. However, in the case of incomplete compaction-consolidation process, even with complete load removal, in a part of the soil body as a result of the swelling process development, areas of additional soil compaction temporarily arise and develop. Thus, with instant total removal from the consolidating soil layer, compressive stresses remain in the soil skeleton and excessive negative pressures in the pore water occur. At the permeable boundaries of the layer, the pressure is equal to zero, and the reconsolidation-swelling process gradually develops in the nearest zones of the layer, causing water inflow into the pores from the boundary drains and, what is especially important, from the middle part of the layer. As a result, in the middle part of such an incompletely consolidated layer, compressive stresses increase and, consequently, excessive negative pressures in pore water increase, i.e. reconsolidation of this part of the soil occurs. Over time, the reconsolidation zone decreases, and then only swelling of the ground occurs in the entire thickness, while the skeleton stress and water pressure gradually decrease to 0 [19]. Thus, if the soil sample is loaded and unloaded again, the above entire process will be repeated. And if the water-saturated soil, which constitutes a two-phase system, is subjected to periodic loading and unloading, the phenomenon of hysteresis appears, which causes a certain loss of mechanical energy.

The purpose of this work is to study the hysteresis effect in water-saturated (two-phase) soils under conditions of multiple compression combined with full unloading, on the basis of a one-dimensional task of filtration compaction (consolidation) of soils, taking into account the creep of the soil skeleton.

Methods and Materials

The study of hysteresis energy losses in water-saturated (two-phase) soils under periodic load changes was based on the general solution of the joint task of creep and consolidation theory for a two-phase soil system derived from the generalized bulk force model, taking into account the interaction of soil phases, time changes in the general stress state at any point of the soil and additional pressures in pore water, and incomplete transfer of external pressure to pore water [12,13].

This solution for the one-dimensional task is written down in the form [12]:

$$S(t) = hm_v p\left[1 + \int_0^t K(t-t_0)dt_0 - \frac{8}{\pi^2}\sum_{m=1,3,\dots}^{m=\infty}\frac{1}{m^2}\psi(t)\right], \quad (1)$$

where ψ(t) is a creep function.

Taking the creep kernel in the form [13]:

$$\overline{K}(t-t_0) = \delta e^{-\delta_1(t-t_0)}. \quad (2)$$

The creep function ψ(t), taking into account the interaction of soil phases, is defined by the expression [12]:

$$\psi(t) = e^{-\left(\frac{\pi m}{2h}\right)^2 c_v t} + \frac{\delta}{\delta_1}\frac{e^{-\left(\frac{\pi m}{2h}\right)^2 c_v t} - e^{-\delta_1 t}}{1-\left(\frac{\pi m}{2h}\right)^2\frac{c_v}{\delta_1}}, \quad (3)$$

where $c_v = k_\phi / m_v\gamma_w$ is the consolidation coefficient of the two-phase soil, 2h is the thickness of the soil layer under bilateral drainage, δ and δ_1 are the creep parameters.

As suggested in the work [12], the formula for the settlement of two-phase soils can be represented as:

$$S(t) = ph\left(m_v^{\mathrm{I}} U_0^{\mathrm{I}} + m_v^{\mathrm{II}} U_0^{\mathrm{II}}\right), \tag{4}$$

where m_v^{I} and m_v^{II} are coefficients of primary and secondary soil consolidation, U_0^{I} and U_0^{II} are degrees of primary and secondary consolidation, respectively. The degree of primary consolidation U_0^{I} is determined by the expression:

$$U_0^{\mathrm{I}} = 1 - \frac{8}{\pi^2}\sum_{m=1,3,\ldots}^{m=\infty} \frac{1}{m^2} e^{-\left(\frac{\pi m}{2h}\right)^2 c_v t}. \tag{5}$$

The degree of secondary consolidation U_0^{II} – by the formula:

$$U_0^{\mathrm{II}} = 1 - e^{-\delta_1 t} - \frac{8}{\pi^2}\sum_{m=1,3,\ldots}^{m=\infty} \frac{1}{m^2}\left[\frac{e^{-\left(\frac{\pi m}{2h}\right)^2 c_v t} - e^{-\delta_1 t}}{1-\left(\frac{\pi m}{2h}\right)^2 \frac{c_v}{\delta_1}}\right]. \tag{6}$$

Taking into account that the total ground settlement is defined by the formula:

$$S_\infty = h m_v^{\mathrm{I}} p\left(1 + \frac{\delta}{\delta_1}\right). \tag{7}$$

And taking into account formula (4), we get the definition of the total degree of consolidation (due to filtration consolidation and simultaneously the creep of the soil skeleton) in the form of [12]:

$$U_0^{\Sigma} = \frac{S(t)}{S_\infty} = \frac{ph\left(m_v^{\mathrm{I}} U_0^{\mathrm{I}} + m_v^{\mathrm{II}} U_0^{\mathrm{II}}\right)}{h m_v^{\mathrm{I}} p\left(1+\frac{\delta}{\delta_1}\right)}. \tag{8}$$

And accepting that

$$m_v^{\mathrm{II}} = m_v^{\mathrm{I}}\left(\frac{\delta}{\delta_1}\right). \tag{9}$$

We get

$$U_0^{\Sigma} = \left(U_0^{\mathrm{I}} + \frac{\delta}{\delta_1} U_0^{\mathrm{II}}\right) / \left(1 + \frac{\delta}{\delta_1}\right). \tag{10}$$

For values of total consolidation degree $U_0^{\Sigma} > 0.2$ in expressions (5) and (6) (for primary and secondary degrees of consolidation) we may limit it to the first term of the series.

Then the expression for the deformation of two-phase soil depending on time, in conditions of one-dimensional task, with a uniform distribution of compaction pressures, taking into account the interaction of phases and skeletal creep, we get in the form of:

$$\varepsilon(t) = m_v \sigma(t) \frac{1 - \frac{8}{\pi^2} e^{-Mt} + \frac{\delta}{\delta_1}\left\{1 - e^{-\delta_1 t} - \frac{8}{\pi^2}\left[\frac{e^{-Mt} - e^{-\delta_1 t}}{1 - M(c_v/\delta_1)}\right]\right\}}{1 + \frac{\delta}{\delta_1}}, \tag{11}$$

where $M = \frac{\pi c_v}{4h^2}$ and $c_v = \frac{k_\phi}{m_v \gamma_w}$, and $\sigma(t)$ is the external load varying in time.

Consider the action of cyclic loading

$$\sigma(t) = \sigma_0[\sin(\omega t + \varphi_0) + \lambda], \tag{12}$$

where ω is the cyclic frequency, φ_0 is the initial phase, λ is a constant determining the degree of asymmetry of cyclic loading.

To determine the hysteresis loop area, which represents the energy $\Delta W(n)$, dissipated in one cycle of deformation, the formula [6] is used:

$$\Delta W(n) = \int_{Tn}^{T(n+1)} \sigma(t) \frac{\partial \varepsilon(t)}{\partial t} dt. \tag{13}$$

And the total mechanical energy W(n) spent in one cycle of deformation is determined by the formula [6].

$$W(n) = \int_{Tn}^{T\left(n+\frac{1}{2}\right)} \sigma(t) \frac{\partial \varepsilon(t)}{\partial t} dt\ , \tag{14}$$

where $T = \frac{2\pi}{\omega}$ is the cycle period, n is the cycle number.

Results and Discussion

The Substituting expressions (11) and (12) in formula (13) to determine the hysteresis loop area (the energy ΔW(n) dissipated in one cycle of deformation) we will get:

$$\Delta W(n) = \frac{m_v \sigma_0^2}{1+\frac{\delta}{\delta_1}} \left\{ e^{-MTn}(1-e^{-MT}) \left[\left(\frac{\lambda\omega^2}{M^2+\omega^2} + \frac{\lambda M^2}{M^2+\omega^2} - \frac{\omega^2}{M^2+4\omega^2} - \frac{M}{2} - \frac{M^2}{2(M^2+4\omega^2)} \right) \left(-\frac{8}{\pi^2} - \frac{8\delta}{\pi\delta_1\left(1-M(c_v/\delta_1)\right)} \right) - \left(\frac{\lambda\omega^2}{\delta_1^2+\omega^2} + \frac{\lambda\delta_1^2}{\delta_1^2+\omega^2} - \frac{\omega^2}{\delta_1^2+4\omega^2} + \frac{\delta_1}{2} - \frac{\delta_1^2}{2(\delta_1-4\omega^2)} \right) \left(\frac{\delta}{\delta_1} - \frac{8\delta}{\pi\delta_1\left(1-M(c_v/\delta_1)\right)} \right) + \left(\frac{\lambda}{M} - \frac{M}{M^2+\omega^2} \right) \left(\frac{8\lambda M}{\pi^2} + \frac{8\delta\lambda M}{\pi^2\delta_1\left(1-M(c_v/\delta_1)\right)} \right) \right] + e^{-\delta_1 Tn}\left(1-e^{-\delta_1 T}\right) \left(\frac{\lambda}{\delta_1} - \frac{\delta_1}{\delta_1^2+\omega^2} \right) \left(\delta\lambda - \frac{8\delta\lambda}{\pi^2\left(1-M(c_v/\delta_1)\right)} \right) \right\} \tag{15}$$

And the expression for the total mechanical energy W(n) expended for one cycle of deformation is obtained by substituting expressions (11) and (12) into formula (14):

$$W(n) = \frac{m_v \sigma_0^2}{1+\frac{\delta}{\delta_1}} \left\{ \frac{2\lambda}{\omega}\left(1+\frac{\delta}{\delta_1}\right) - \frac{8}{\pi^2}\left[\lambda e^{-MTn}\left(1+e^{-\frac{MT}{2}}\right) - \frac{M^2+3\omega^2}{M^2+4\omega^2} e^{-MTn}\left(1-e^{-\frac{MT}{2}}\right) \right] + \frac{8\lambda M}{\pi^2}\left[\frac{\lambda}{M} e^{-MTn}\left(1-e^{-\frac{MT}{2}}\right) - \frac{M}{M^2+\omega^2} e^{-MTn}\left(1+e^{-\frac{MT}{2}}\right) \right] - \frac{\delta}{\delta_1}\left[\lambda e^{-\delta_1 Tn}\left(1-e^{-\frac{\delta_1 T}{2}}\right) - \frac{\delta_1^2+3\omega^2}{\delta_1^2+4\omega^2} e^{-\delta_1 Tn}\left(1+e^{\frac{\delta_1 T}{2}}\right) \right] + \delta\lambda\left[\frac{\lambda}{\delta_1} e^{-\delta_1 Tn}\left(1-e^{-\frac{\delta_1 T}{2}}\right) - \frac{\delta_1}{\delta_1^2+\omega^2} e^{-\delta_1 Tn}\left(1+e^{\frac{\delta_1 T}{2}}\right) \right] - \frac{8\delta}{\pi\delta_1\left(1-M(c_v/\delta_1)\right)}\left[\lambda e^{-MTn}\left(1+e^{\frac{MT}{2}}\right) - \frac{M^2+3\omega^2}{M^2+4\omega^2} e^{-MTn}\left(1-e^{-\frac{MT}{2}}\right) \right] + \frac{8\delta\lambda M}{\pi\delta_1\left(1-M(c_v/\delta_1)\right)}\left[\frac{\lambda}{M} e^{-MTn}\left(1-e^{-\frac{MT}{2}}\right) - \frac{M}{M^2+\omega^2} e^{-MTn}\left(1+e^{\frac{\delta_1 T}{2}}\right) \right] + \frac{8\delta}{\pi\delta_1\left(1-M(c_v/\delta_1)\right)}\left[\lambda e^{-\delta_1 Tn}\left(1+e^{\frac{\delta_1 T}{2}}\right) - \frac{\delta_1^2+3\omega^2}{\delta_1^2+4\omega^2} e^{\delta_1 Tn}\left(1-e^{-\frac{\delta_1 T}{2}}\right) \right] - \frac{8\delta\lambda}{\pi^2\left(1-M(c_v/\delta_1)\right)}\left[\frac{\lambda}{\delta_1} e^{-\delta_1 Tn}\left(1-e^{-\frac{\delta_1 T}{2}}\right) - \frac{\delta_1}{\delta_1^2+\omega^2} e^{-\delta_1 Tn}\left(1-e^{-\frac{\delta_1 T}{2}}\right) \right] \right\}. \tag{16}$$

The absorption coefficient Ψ(n) is determined by the formula [7, 21]:

$$\Psi(n) = \frac{\Delta W(n)}{W(n)}\ . \tag{17}$$

Applying in expressions (15) and (16) experimentally obtained parameters of filtration and deformation (skeleton creep parameters) of soil, we can obtain the spent energy ΔW(n) for one cycle of deformation and dissipation factor Ψ(n) for two-phase (water-saturated) soil.

Conclusion

Thus, on the basis of this solution we will be able to:

1. Examine the dependence of dissipative properties of two-phase (water-saturated) soil on its filtration and deformation characteristics.

2. Control and regulate the dissipative properties in process of interaction and relationship of water-saturated soil phases.

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HYDRAULIC PRESSURE MANAGEMENT OF YEREVAN CITY'S WATER SUPPLY SYSTEMS

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Abstract: *The system's excessive pressure management after zoning is essential for improving the existing water supply operation efficiency. Our original research proves that pressure control reduces the leaks in the water supply network, increasing the reliability level of the internal and external networks and saving energy consumed in pumping systems. In recent years, 243 pressure regulating valves (PRV) have been installed in the 97 zones of the expanded water supply network in the Yerevan city (the difference between the levels in the city reaches up to 500 meters) for pressure control in complex terrain conditions.*

Keywords: *water supply network, pressure regulating valve, network zoning, pressure management, excess pressure, water loss reduction*

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Introduction

The distribution network should be zoned in complex terrain conditions when there are differences in levels between residence boundaries. The need for zoning can arise in both pumping and gravity systems (reverse zoning) [1,4]. In this case, there is excess (unacceptable) pressure in the network before zoning and pressure management. This regulation reduces leaks and improves the conditions under which plumbing equipment and reinforcement operate, reducing the water consumption and the amount of electricity consumed in pumping systems.

Pressure management in the water supply network also reduces the probability of failures in the system and thus operational costs.

Results showed that pipe breaks could be decreased 18% to 30% by reducing the mean pressure for the investigated cohorts of asbestos cement and cast iron pipes. Pressure range reduction could provide larger impacts on both pipe materials. These results indicate that proactively controlling the hydraulic pressure may have a potentially significant impact on the reliability and sustainability of water supply networks [9]. The reliability of water supply infrastructure is critical for the continuous and uninterrupted provision of clean water. A major problem that affects the normal operation of water supply networks is the occurrence of pipe breaks. Current research suggests that pipe breaks result from complex interactions of physical, environmental and operational factors that impact the deterioration rate and breaks of pipes [8,10]. However, many causes for pipe breaks are still not fully understood and accounted for. For example, high levels or sudden changes of hydraulic pressure could be significant contributing factors for pipe breaks [11,12]. Nonetheless, there has been insufficient empirical evidence to develop methods that can quantitatively determine the impact of hydraulic pressure on pipe breaks in operational networks. Furthermore, it is unclear which metrics of the hydraulic pressure are most causative for the occurrence of pipe breaks; e.g. mean pressure, pressure range and pressure transients.

The zoning problem becomes particularly important in cases where high-rise multi-apartment buildings are built in neighborhoods inhabited by one- or two-story buildings. In the past, an ineffictive pressure control method was used to avoid excessive pressure in the Yerevan city water system: the opening of some valves of

the distribution network was reduced, which resulted in all the above negative phenomena present in the network. Therefore, it is essential to implement effective network zoning or to divide the network into several zones, i.e. to isolate them hydraulically from one another, so as to maximize the controllability of the distribution network in Yerevan. Isolation can be implemented by installing existing or new valves, which will be closed during the water supply network's normal operating conditions, and can be opened if necessary. In Yerevan conditions, it is advisable to apply vertical zoning with a sequential or parallel scheme [2, 3].

Our original research showed that some additional problems arise when creating zones using existing constructed or reconstructed, prefabricated or fragmented zones. After zoning a number of town districts, it became apparent that the zone's water supply had fallen by just 8–10% and that the supply's 8–hour duration had become 12–hours rather than the intended round-the-clock. The required design pressure was also not maintained, so the frequency of failures increased. Additional studies have found that the main reason for poor zoning efficiency is the application of incorrect pressure management principles.

To overcome the mentioned shortcomings, we developed special approaches. However, these issues were not taken into account during the development of Yerevan water supply network.

Materials and Methods

The zoning of the water supply in Yerevan started in 2005. During the planning of the zone, the district's existing projects of the water supply network, as well as knowledge of experienced operators, original study results, and data obtained through pipe routing, metal detecting, and output measurement devices have been used.

Pressure meters and telecommunications software were installed at different points of the network to determine the hydraulic distribution scheme in the district water supply network. As a result of multidisciplinary original studies, the hydraulic connections of the planned zone with the neighboring zones, as well as their impact on the zone's functionality were found. To properly zone the area, it was necessary to disconnect all extra connections found supplying the district, leaving only the main one and to check out the possibility of increasing the amount of water supplied as to maintain the water supply level.

After, the availability of hydraulic connections between the different districts was investigated. It was found that each zone has many connections that link the zone under consideration to adjacent zones with lower pressure. After hydraulically isolating and demarcating the water supply zone, measurements of discharges and pressures show that there was a significant change in parameters compared to the measurements taken in the initial stage. To regulate the isolated zone pressure, to avoid excessive pressure, and to use the energy in the position rationally, the next step is to determine the amount of pressure required in the sectors created in the zone area. Based on our regulatory requirements and operational experience, we have established the following necessary pressure levels in Yerevan: in districts where 1-2-story private houses have been built - up to 20 meters, for 5-story buildings - 27-30 meters, and in multi-story buildings it is advisable to supply the required pressure with local pumping stations because higher pressure increases the network emergency and water losses.

The reduction in pressure must not result in pressure that is below the minimum regulatory pressure for serviceability, e.g. a surrogate value of 15m pressure head (1.5 bar) in water distribution pipes is used in the UK for the minimum regulatory pressure. Reliable estimation of the impact of hydraulic pressure control on pipe breaks would allow operators to quantify extra benefits of pressure management on reducing the number of pipe breaks and increasing the life cycle of ageing infrastructure [9]. Currently, the benefits from implementing pressure management are evaluated on the basis of potential leakage reduction, for which the relationships of pressure and leakage are relatively well understood [14-16]. Pressure management schemes are implemented if the benefits exceed the installation and maintenance costs [15]. Although water utilities recognise that the reduction in hydraulic pressure may decrease pipe breaks [12,15,17], the lack of empirical

evidence and robust estimation methods have limited the inclusion of the potential reduction in pipe breaks in cost–benefit models for pressure management schemes [15].

The decommissioning of local pumping stations is one of the fundamental problems of pressure management in the water supply area. The reconstruction resulted in 113 of the 509 pumping stations being decommissioned in the reconstruction zones. Pumps remaining in operation were replaced with modern ones having a high-efficiency coefficient and reliability. We should also add that before the zoning, the pumps worked on an 8-hour schedule, and after the reconstruction, they worked around the clock. Meanwhile, after the reconstruction, the energy consumption in the existing pumping stations was reduced by 6 times, and in the zones, by 12 times. In some cases, the reconstructed zones' level differences are 150 meters, therefore, 243 pressure regulating valves (PRV) had to be installed once the aforementioned operations were completed.

High hydraulic pressure leading to excess pressure in water supply networks can be controlled with the use of PRVs, which commonly are membrane operated globe valves. PRVs dynamically reduce excess pressure in a network by introducing local energy losses. Recent developments in electronic pilots for PRVs allow for the implementation of different control profiles for PRVs that can either be time based (time modulation) or demand based (flow modulation) [13,14]. The control profiles can be remotely modified to significant flexibility in managing the pressure in large scale water supply networks.

Pressure management during zoning

In established water supply zones, pressure management is an important issue. To avoid excessive or insufficient pressures in the network, it was necessary to use modern computer programming for hydraulic calculations of the water supply network, which determined the calculated values of the outflows and pressures in the network sections and compared them with the actual values [5-7]. The program can be used to identify the water supply network's most crucial and susceptible locations, as well as its installation points and pressure regulators' diameters.

Rezaei et al. [12] investigated a case study of 48 DMAs and reported that pipe break rates had a positive correlation with high pressure variations. Martinez-Codina et al. [11] implemented an statistical analysis to assess differences in the pressure cumulative distribution function of pipes conditioned to break against random pipes. Their analysis comprised the evaluation of various hydraulic pressure metrics. It was observed that the pressure range, which is the difference between maximum and minimum pressure, provided the biggest difference in the presented cumulative distribution functions. Martinez-Garcia et al. [18] performed a spatiotemporally based clustering analysis to assess the correlation of consistent high pressure with pipe failure rates. Results from this study showed that there was a strong correlation between high pressure and pipe breaks in areas with high failure rates. However, weak correlations were also observed in other areas, suggesting that the effects of pressure could be spatially dependent. Further research is required to allow operators to assess the benefits of active pressure control for the reduction of pipe breaks in water distribution and transmission pipes.

While previous studies on analysing the hydraulic pressure as a factor for pipe breaks are limited [11,12,15,18–20], a multitude of published studies have investigated general models for pipe failures prediction. These models can be broadly categorised in mechanistic and data driven [21–23]. Mechanistic approaches usually require expensive, in field, data collection to analyse the deterioration state and estimate fracture of critical elements in the networks [24]. Data driven approaches make use of historical datasets and several covariates to estimate pipe breaks probabilities or breaks rates. This can later be used to assist in the allocation of resources for rehabilitation and replacement [8]. Data driven models can provide different outputs depending on how the algorithms are adapted. Support vector machines and neural networks have been applied to predict the rate of pipe breaks [25,26], while evolutionary polynomial regressions have been applied to predict the number of pipes breaks [27]. Boosted decision trees [28] and logistic regression [29,30] have been utilised to predict pipes breaks for individual pipes.

The number of water pipe failures and the probability of their occurrence depend on the following factors: the presence of excess pressure, a sharp change in the working pressure in the network, the material of the pipe, its quality, wear, as well as the pressure increase in the zone at night time. All the mentioned factors are present in Yerevan's water supply network, so pressure regulation problems are vital.

In the conditions of city area cut relief, we find it appropriate to solve the problem of pressure regulation by pressure regulating valves. With the aid of this device, the water supply network, the plumbing equipment, and reinforcement are protected from excessive pressure and hydraulic shock. The valve-sized device, after its location, reduces and stabilizes the pressure in the water supply network by means of a diaphragm and a spring (Fig.).

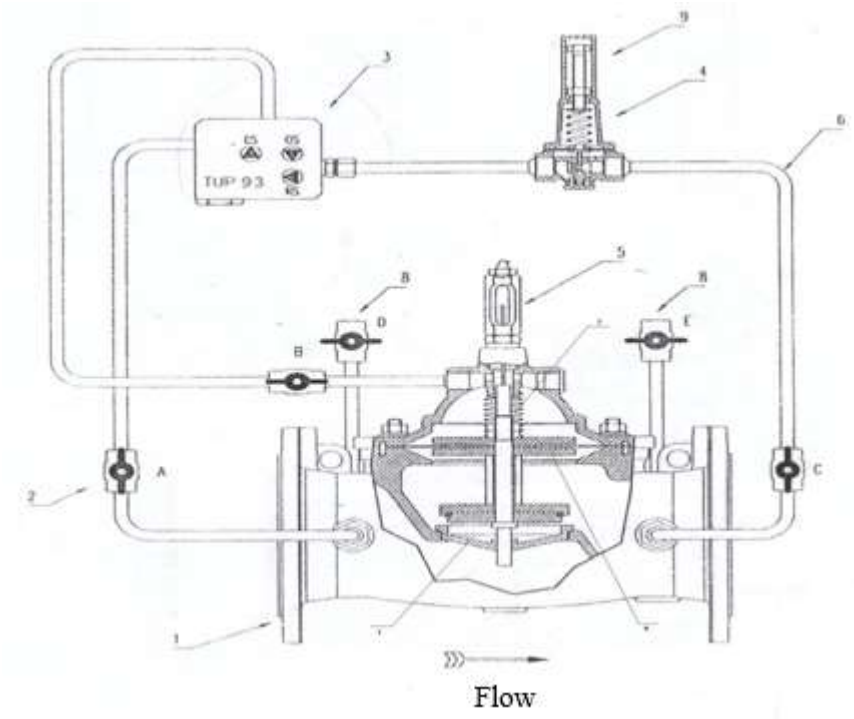

Fig. *Principle scheme of the pressure regulator operation*

1. Plate valve, 2. Isolating ball valve (A-B-C), 3. Central control panel, 4. Pilot valve, 5. Valve position indicator, 6. Diaphragm, 7. Spring, 8. Manometer mounting ball valve (D-E), 9. Pilot-operated valve cover

The pressure regulator operation principle is based on the activation of the diaphragm as a result of pressure changes, above and below of which the main and additional springs are installed. The spring is in a free position before starting and is adjusted by the pilot valve screw within permissible pressure limits for the given spring. After the pressure regulating valve installation point, the pressure in the pipeline is regulated within the permissible limit defined for controlling the system. If the pressure rises above the set point, the diaphragm presses the main spring, allowing the plate valve to pull the additional spring up and restrict the water flow through the adjustment/control valve. The main valve closes with pressure increase in the static part of the pressure regulating valve. Thus, the control valve inhibits the increase in pressure rise after itself, returning the pressure to the preset value. The valve closing rate can be adjusted via the central control panel.

Results and Discussion

The number of water pipe failures and the probability of their occurrence depend on the following factors: the presence of excess pressure, a sharp change in the working pressure in the network, the material of the pipe, its quality, wear, as well as the pressure increase in the zone at night time.

Considering that the regulator diameter is selected according to the output, therefore, it is selected approximately at the design stage of the water supply pressure zone, as reducing the losses, the output will further decrease.

In the conditions of Yerevan, it is recommended to choose the regulator diameter with the minimum output of water demand: Kc = Kmin, where Kc is the conditional throughput of the regulator (m^3/h), Kmin is the minimum output recorded at the installation point (m^3/h), which is mainly recorded at night, between $1^{00} – 5^{00}$.

After selecting the device, its operation should be checked under the conditions of maximum water consumption outputs based on the device's technical documentation. Practically, it is sometimes necessary to reduce the diameter of the regulator after loss reduction.

The estimated pressure drop value determination through the regulator is quite an important and complex issue because the cavitation phenomenon in the regulator, as well as durability, quality and noiseless operation depend on that value. Based on the above, we recommend to observe the following conditions when choosing a regulator:

- the water flow rate in the regulator should not exceed 4m/s,
- the pressure in the regulator should not decrease more than 3 times: $h_{inlet} \leq 3h_{outlet}$,
- the output pressure in the regulator must ensure the pressure in the network after the regulator: $h_{output} = H_p + h_{pipe} + h_{reg}$, where h_{pipe} is the pressure loss in the pipelines to the first consumer (m), h_{reg} is the pressure loss in the regulator (m), H_p is the required pressure in the network after the regulator (m).

We can also add that it is preferable to regulate the pressure (reduce) after the start, at least within a week, since a sudden drop in pressure results in a very unfavorable reaction from the consumer.

The installation of a pressure regulator, besides the primary functions, can also contribute to the durability of plumbing equipment and reduce water consumption.

Conclusion

The studies showed that using the existing distribution system and considering the position of reservoirs, placement, relief of the site, and the number of floors in the buildings, Yerevan city water supply network should be converted into 97 hydraulically isolated zones. After the zoning, it became necessary to develop principles of excess pressure management and determination of optimal pressure in zones, as a result of which 243 pressure regulating valves were installed in recent years.

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SOME CONSTRUCTIVE METHODS FOR IMPROVING THE OPERATION OF HORIZONTAL SETTLING TANKS

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Abstract: *The main constructive methods for improving the process of settling suspended solids and separating sediment in horizontal settling tanks are considered. Methods for calculating these structures are analyzed both in general terms and for individual characteristic (supply, settling and drain) areas of wastewater flow. Those constructive proposals that can more significantly improve the efficiency of horizontal settling tanks are noted. The proposed modification relates to the part built into the thin-layer sedimentation tank - the flocculator, which ensures the most uniform and laminar flow in the structure.*

Keywords: *horizontal settling tank, structural modifications, suspension particle, flocculator, laminarizing devices*

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Introduction

The advantages of horizontal settling tanks compared to other types are low depth, possibilities of operational improvement through structural modifications, the cleaning effect, both in normal conditions and by using thin-layer elements; the possibility of using one rating device for several sections and a successful combination of the integrated parts of the sand trap or flocculator, etc.

Based on the accepted schemes and considering the maximum laminarizing conditions of the wastewater flow, the preferred design of horizontal settling tanks is selected and an incorporated modified flocculator with thin-layer elements is proposed.

Materials and Methods

The proposed constructive modification of the horizontal settling tank is based on comparative and generalizing methods that, in principle, can improve the operation of the equipment. The most promising methods for calculating these structures are also given.

Main Part

Among the methods used for the technological calculation of settling tanks, the most promising are those that allow more fully to consider the actual conditions of sludge deposition and the relationship between the design parameters. Among these parameters, the most important is the retention time necessary for obtaining the desired clarification effect and the deposition rate of those particles that must be detained in the settling tank. The equation expresses the relation:

$$T = H/(U_0 - \omega), \quad (1)$$

where:

T - the retention time,

H - the accepted working depth of the running part of the settling tank,

U_0 - minimum deposition rate of detained particles in wastewater at rest,

ω - the additional resistance of the suspended particles when water flows through the settling tank [1].

In general, the length of a horizontal settling tank can be found by the formula:

$$L = (V \cdot H / \omega_{oc}), \quad (2)$$

where:

L - the length of the settling tank, m,

V - fluid flow in the settling tank, m/s,

H - settling tank depth, m,

ω_{oc} - particle deposition rate in the tank, m/s.

In turn, the particle deposition rate can be found by the formula:

$$\omega_{oc} = 1/18(d_m \cdot \rho_k \cdot g)\mu_{ж}, \quad (3)$$

where:

d_m - the minimum equivalent diameter of the suspended particles, m,

ρ_k - apparent particle density, kg/m^3,

g - free fall acceleration, 9.81 m/s^2,

$\mu_{ж}$ - dynamic viscosity of the liquid, pa·s.

In horizontal settling tanks, it is recommended [2] to determine the vertical component of the flow rate from the equation:

$$\omega = KV_{cp}^n, \quad (4)$$

Or from the correlation graphs K and V_{cp}.

The coefficient K has a constant value: $n = 2$ at $V_{cp} < 15$ mm/s and $n = 3$ at $V_{cp} > 15$ mm/s.

The absolute value ω in the range of flow rate equal to 5…10, 10…15, and 15…20 mm/s is 0.05, 0.1 and 0.5 mm/s respectively.

Since the height of the main water layer of the fluid flow in the settling tank is always less than the calculated depth of the structure, the actual flow rate V_{ϕ} in the settling tank always exceeds those average V_{ϕ} and their values:

$$V_{cp} = q/(B \cdot H), \quad (5)$$

which are included in the calculation equations when determining the flow section $A = B \cdot H$ and the length L of the settling tank.

The difference between the values V_{ϕ} and V_{cp} is especially huge in the beginning and the end of the settling tank. It is just these areas that are zones of chaotic whirlpools and therefore require constructive improvements.

Considering the above characteristics, it can be said that a more detailed calculation of horizontal settling tanks is reduced to determining the dimensions of its flow (operational) and sedimentary parts according to the corresponding calculation schemes (Fig. 1).

It should be noted that, according to [2], the results of calculations of settling tanks carried out according to the scheme of Fig. 1a) differ significantly from the performance indicators of their operation.

For the hydrodynamic conditions of horizontal settling tank operation improvement, it is necessary to create designs for the wastewater inlet and outlet that will ensure their uniform distribution over the width and depth of the settling tank.

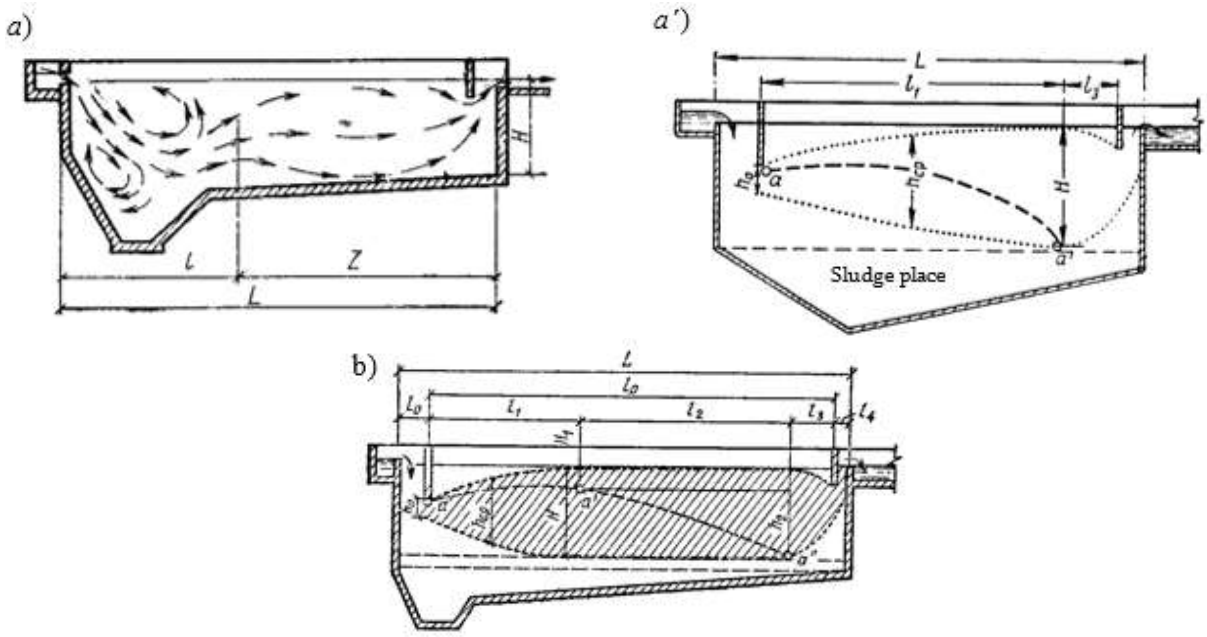


Fig. 1. *Calculation schemes of horizontal settling tanks*
a) - taking into account two [3], b) - taking into account three characteristic sections [4]

Here, the flow distribution is more uniform than in Fig. 1b, since the incoming wastewater is directed to the end wall of the settling tank. At the beginning of the settling tank, the sludge is agitated, and the re-sedimentation of such sludge is much faster and more complete than in the initial settling. As a result, the horizontal settling tanks' characteristic areas must be calculated in accordance with the schemes presented in Figs. 1b and 2.

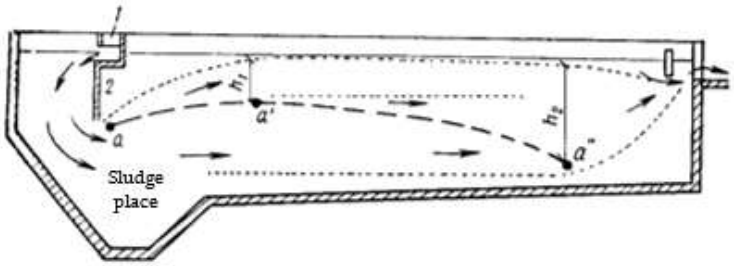


Fig. 2. *Scheme of waste water distribution through spillways*
1 - water supply tray, 2 - training wall

In the inlet section, the flow rate in the settling tank will be

$$V_1 = V_{cp} \cdot H / h_{cp} . \tag{6}$$

A particle settling at such a rate will experience a braking force, which will reduce its downfall.

The length of the inlet section will be equal to

$$l_1 = t_1 \cdot V_1 , \tag{7}$$

where t_1 is the time during which the suspended particle from the initial point α moves to the point a', passing along the vertical path:

$$h_1 = t_1 \cdot (U_0 - \omega). \tag{8}$$

It will take time for this particle to sink into the sludge place of the settling tank (at the point a'')

$$t_2 = \frac{H - h_1}{U_0 - \omega'}, \tag{9}$$

where ω' is the additional resistance for a particle settling in a flow that moves at a rate V_{cp}.

For given t_2, we have

$$l_2 = t_2 \cdot V_{cp}. \quad (10)$$

At the end of the settling tank, the flow rate increases (Fig. 1b), and the settling conditions deteriorate sharply. The section length with an increased rate depends on the settling tank depth and the structure of the discharge device. For the conventional spillways, it is:

$$l_3 = H/tg\alpha, \quad (11)$$

where α is the flow convergence angle at the outlet of the settling tank, equal to 25…30 °.

Thus, the estimated length $(L_{p.})$ of the settling tank is determined as the sum of its main sections:

$$L_{p.} = l_1 + l_2 + l_3. \quad (12)$$

The first semi-submerged partition is a training wall; it is installed at a distance of l_0 = 0.5 ... 1.0 m from the spillway of the water supply stream; the second serves to keep substances floating in the settling tank and is installed at a distance of l_4 = 0.2 ... 0.3 (0.5) m from the spillway at the end of the settling tank. Thus, the construction length of the horizontal settling tank exceeds the calculated one by about 1.0…1.5m [5,6].

Distribution grids positioned across the settling tank are sometimes used instead of semi-submerged partitions.

Fig. 1a′ refers to cases in which the uniform translational water flow across the entire flow section of the settling tank is achieved only at the outlet, the value is $l_2 = 0$ (in relatively short settling tanks).

Instead of H, its average depth (h_{cp} = 1.5 ... 2.0 m) is taken as the initial estimated depth, since not only the required settling time, but also the usable volume of the structure depends on the settling tank depth, that is the depth which should be taken as the initial value in its calculation. Schemes of uniform wastewater distribution in the settling tank with various training devices are also used (Fig. 3).

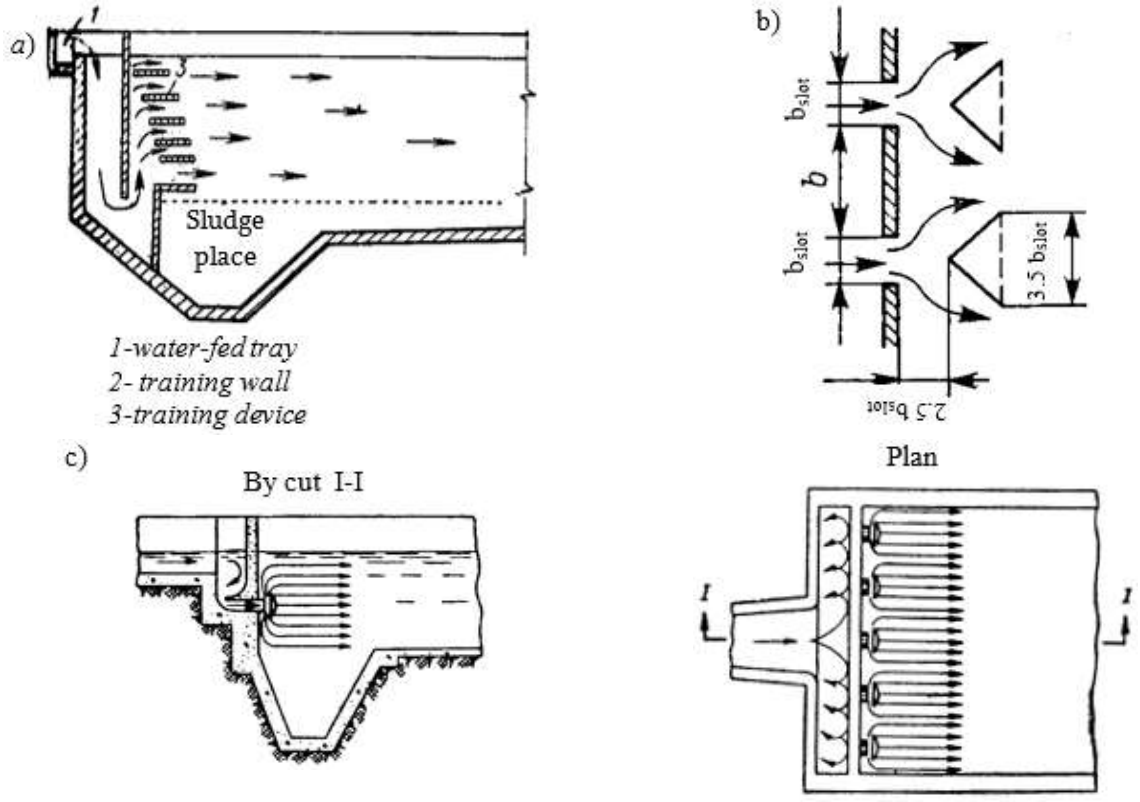


Fig. 3. *Schemes of dispatch devices*

a) - proportional shelf device [2], b) - slotted partition with reflectors [7], c) - disk device [6]

For more complete use of the flowing part volume, several drainage trays are arranged at the end of the settling tank instead of a spillway. Best results are achieved by placing the trays in the last third of the tank length. The working effect of such settling tanks increases by about 5% [2].

Horizontal settling tanks with a vertical flow of settled wastewater are also used in practice (Fig. 4).

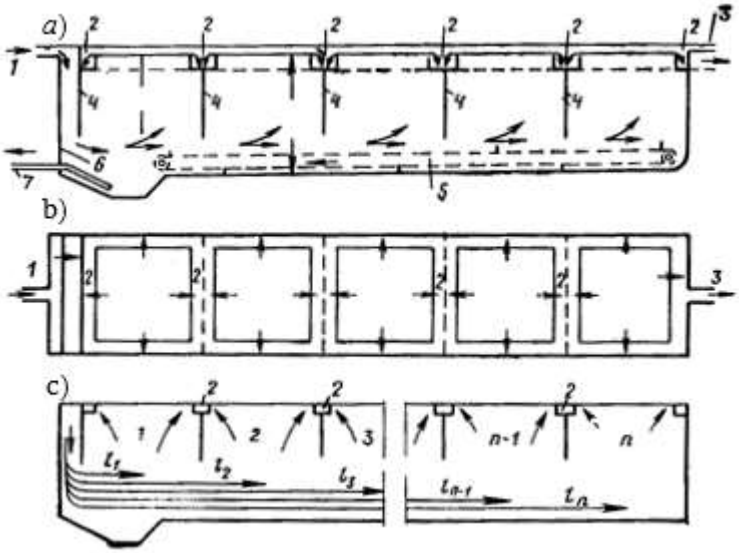


Fig. 4. *Scheme of a horizontal settling tank with vertical partitions*
a) and b) - section and plan, c) - design diagram, 1-water supply channel, 2- drained trays, 3-drainage channel, 4-walls, 5-scrapers for raking sediment, 6-training shield, 7-sludge pipe

This construction type is a constructive modification of settling tanks with dispersed removal of clarified water. However, the productivity of a settling tank with semi-submerged partitions is 30–50% higher than conventional settling tanks. However, their assessment is challenging because of the complex movement of treated wastewater [2].

Constructively, the settling process can also be improved in the settling zone if this zone is divided into thin plates or pipes. Here, settling takes place in the space between the plates, with the height of 20…150mm. Wastewater moves along the plane of the plates inclined by $50…60^0$ while solid particles are detained on the plates and roll up into the sludge collectors.

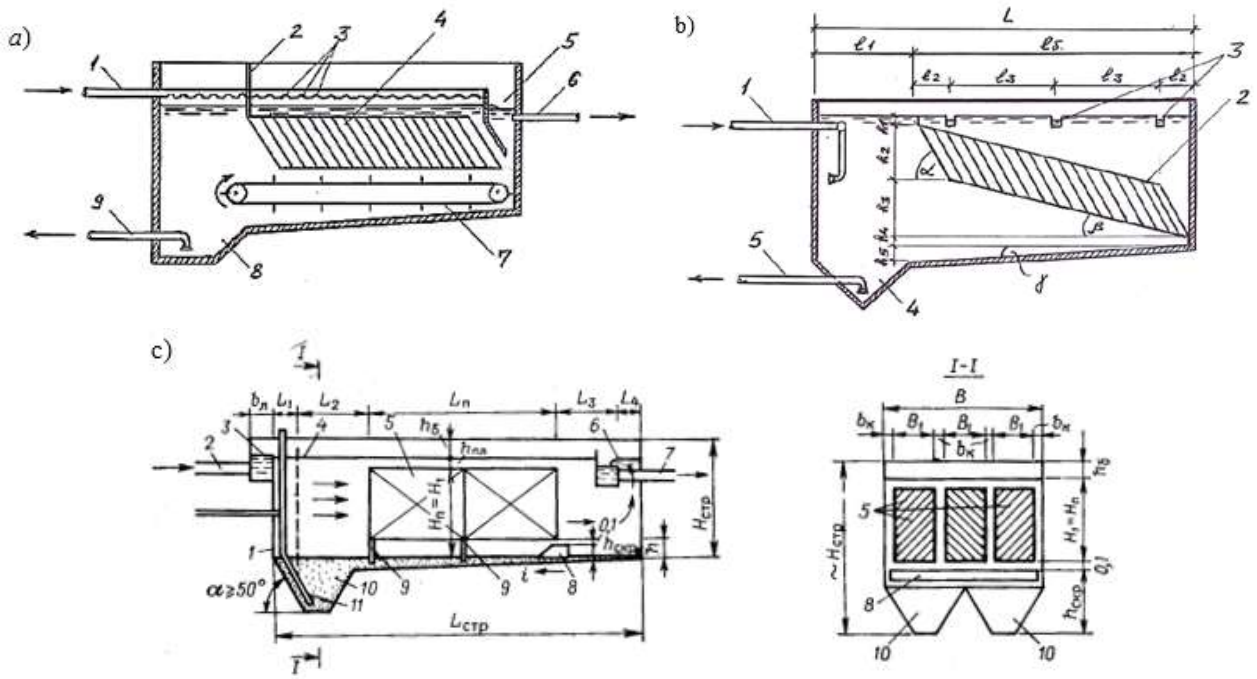
Reducing the settling height decreases the turbulence, characterized by the vertical component of the wastewater flow pulsation, resulting in an increase in volume utilization factor and a decrease in the settling time (up to several minutes). The reconstruction of various types of operating settling tanks uses the thin-layer settling principle. The performance of reconstructed settling tanks can be increased by 2 to 4 times using this technique, which is thought to be the most cost-effective and occasionally the only one that can be used.

Besides the sedimentation process intensification and a significant increase in clarification effect, the benefits of thin-layer sedimentation tanks include operation stability to changes in the fluid temperature, contaminant concentration, and even significant fluctuations in the treated wastewater flow rate[1] [8].

There are three schemes for water flow in a thin layer: direct-flow, countercurrent, and cross-flow. With a cross-flow design, the precipitated sediment moves perpendicular to the movement of wastewater and with direct-flow and countercurrent flow, respectively, toward the wastewater or in the opposite direction.

The characteristic schemes of horizontal thin-layer settling tanks with some design modifications are presented in Fig. 5.

[1] Raschet i proyektirovaniye tonkosloynykh otstoynikov dlya ochistki prirodnykh vod (in Russian). https://vunivere.ru/work52494/page14



a) 1. feed perforated pipeline, 2. support for fastening thin-layer elements, 3. hole, 4. block of thin-layer elements, 5. tray of clarified waste water, 6. outlet pipeline with clarified waste water, 7. scraper mechanism, 8. sink, 9. pipeline for sediment removal

b) 1. feed pipeline, 2. block of thin-layer elements, 3. trays for removal of clarified waste water, 4. sink, 5. pipeline for sediment removal

c) 1. frame, 2. supply pipeline, 3. inlet tray with a spillway, 4. distribution device, 5. block of thin-layer elements, 6. collection tray with a spillway, 7. clarified wastewater pipeline, 8. scraper, 9. flexible partitions, 10. sink for sediment, 11. pipeline for sediment removal

Fig. 5. *Schemes of horizontal thin-layer settling tank operation*
a) - direct-flow [9], b) counter-current [10], c) cross-flow [7]

Horizontal thin-layer settling tanks with a flocculation chamber can also operate according to the above schemes when various reagents are used. Fig. 6 shows such built-in flocculators operating according to countercurrent and cross-flow schemes since it was according to these schemes that the authors of the article got high values for wastewater treatment of the textile, knitwear, and silk industries in early studies [11].

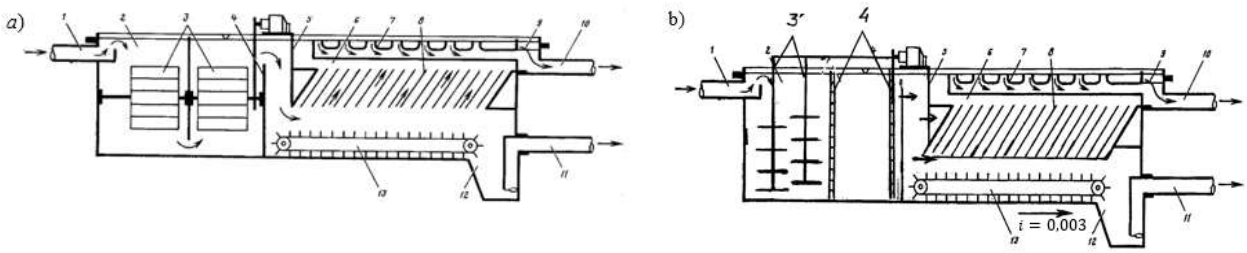


Fig. 6. *Schemes of built-in flocculators*
a) countercurrent [2], b) cross
1. waste water supply, 2. chamber of flocculator, 3. mixers on the horizontal and vertical axes, respectively, 4. drowned spillway, 5. deflector, 6. horizontal settling tank, 7. drain trays, 8. thin-layer plates, 9. side collecting channel, 10. drainage of treated sewage), 11. hydraulic sludge removal system, 12. mud pit, 13. sludge scraper *for precipitate removal*

[2] B.N. Frog, A.P. Levchenko, Vodopodgotovka. Moscow State University, Moscow, 1996

The proposed modified flocculator operates according to a cross scheme (Fig. 6b), in which, instead of a flooded spillway and a training semi-submerged partition, there are paired distribution (perforated) walls, which provide maximum laminarization of the wastewater flow. According to preliminary calculations, the distance between distribution partitions (considering the numerical model developed in [12]) can be taken to be (1/12 – 1/10), but not over 3-4m.

In Fig. 7 a thin-layer settling tank is presented with three sludge pits, working according to a cross scheme.

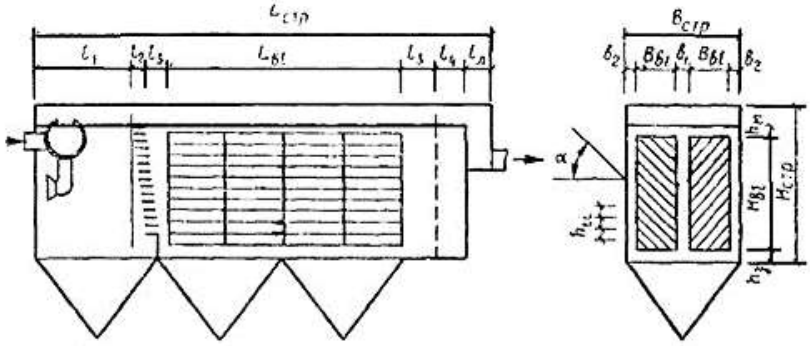


Fig. 7. *The design of a thin-layer settling tank with a cross scheme*

Proposals

On the whole, constructive proposals for the efficient operation of horizontal thin-layer sedimentation tanks are:

1. to ensure an even distribution of the wastewater flow between all thin-layer elements,
2. the uniform mixing of the flow with reagents, which is carried out in the proposed version using vertical mixers arranged in a checkerboard pattern (three in the first row, two in the second) with opposite rotations of the blades,
3. to forecast the distribution zone expansion along the settling tank (about 20 degrees in plan) in order to prevent vortex flow.

Conclusion

After analyzing the structural proposals of horizontal settling tanks using reagents with a built-in flocculation chamber, the structure presented in Fig.6 is the most optimal.

For general (reagent-free) settling, we keep to the structure presented in Fig. 7. In this case, the following advantages are provided:

1. a sufficient zone is formed for sediment stirring-up (Fig. 2),
2. a perforated partition and a horizontal training device at the beginning of the settling tank provide the most uniform wastewater flow,
3. the processes of clarification of the runoff and sedimentation are improved with the help of a perforated partition at the end of the settling tank and several sediment catch sinks.

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A COMPLEX ORGANOMINERAL ADMIXTURE FOR CEMENT SAVING

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Abstract: *The aim of the research is to prepare a composition of a complex organomineral admixture based on industrial waste for cement saving, to experimentally establish the optimum crushing degree of an ash-and-slag waste composition and to estimate the ratio between mineral and organic components of the complex admixture, ensuring the possibility of reducing cement consumption without loss of concrete strength. As a mineral component of the complex admixture the wastes from thermoelectric power stations were used, representing by an ash-and-slag waste composition crushed to a fine powder condition. Optimization of the complex admixture is carried out using mathematical methods of the theory of planning experiments.*

As a result of this research a quadratic polynomial model of influence of crushing fineness of ash-and-slag wastes and cement consumption on concrete strength has been obtained. It is established, that depending on the degree of crushing of ash-and-slag waste composition within values of specific surface of received powder from 2400 to 4000 cm^2/g it is possible to reduce cement consumption by 8-18 % without loss in strength of concrete. The introduction of complex organomineral admixtures into concrete is very effective as it saves cement. However, special studies are required in each case. The compositions of the new complex admixtures are tested on the basis of traditional raw materials, and economic efficiency in saving cement is established. It is proposed to use the methodology of mathematical modelling of the technological complex system under study, presented in this article.

Keywords: *organomineral admixtures, industrial waste, mathematical modelling, cement saving.*

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Introduction

The problem of cement saving in construction is caused by the cement market conditions in the country. Cement plants in operation today were built during the Soviet era.

Existing cement plants have already reached their production capacity and yet are unable to satisfy the needs of the construction industry.

The establishment of new cement plants requires large investment outlays. The investment required to put each cement plant into production in total is around ₽7 billion over three years, which can only be recouped in 6-7 years [1]. The cement deficit today, due to the current geopolitical situation, cannot be overcome by imports. Another reason is that there are no special terminals for bulk cement loading. The transportation of imported cement by Railways is complicated by the inadequate capacity of the transport lines. This fact actualizes the problem of overall saving of cement in construction.

Saving cement is extremely actual when thinking about the environmental protection. It is estimated [2] that cement production will require about 5% of the world's industrial energy. At the same time, the production of each tonne of cement is associated with up to 1 tonne of carbon dioxide emissions into the environment, increasing the risk of global climate change.

The development of high-functional concretes provides an opportunity for significant cement savings [3-5].

High-functional concrete technology involves the use of complex organo-mineral admixtures (OMA). Such

admixtures consist of highly dispersed mineral components and organic modifiers [6-8].

OMA are becoming increasingly widespread in construction practice, as the use of effective superplasticisers as organic components increases.

Mineral components of OMA can be various industrial wastes (keramzite dust, opoka, microsilica, etc.), as also finely crushed metallurgical slags, brick scrap, fuel wastes from thermal power stations and many other industrial mineral wastes. The selection of mineral component for OMA requires special research and depends on specific local conditions as well as on technical and economic efficiency of the results obtained.

In the research study prospects of obtaining an effective organomineral admixture using finely crushed ash-and-slag waste of Novocherkasskaya thermoelectric power station as a mineral component are considered.

Materials and research methods

The base material - the composition of concrete, developed and prepared at the enterprise LLC "BETON DON", Rostov-on-Don for technology of monolithic house-building. The prepared concrete mixture has the workability grade P4, is delivered to the construction site by concrete mixers, is delivered by concrete pumps to the formwork.

The basic consumption of components for concrete mixture preparation was as follows: cement - 350 kg/m^3, sand - 690 kg/m^3, crushed stone - 1120 kg/m^3, water - 200 l/m^3, superplasticizer additive - 7 kg/m^3 (2 % of cement consumption).

Material Consumption

Portland cement CEM I 42,5H of Sebryakov cement plant was used as a binder for the preparation of concrete mixture of mark B25/P4.

As a coarse aggregate used fraction 5-20 mm of crushed stone from Potapovsky sandstone quarry, Rostov region, grade 1200 of crushability.

The fine aggregate was sand of Leventsovskoye sand quarry in Rostov region with particle size modulus Mk = 1.56.

Superplasticizer from «Sky Trade Company» St 2.1 in accordance with TU 5745-004-9459066-2012 was adopted as an organic component for OMA. Superplasticizer is a solution of 25 percent concentration.

The technology of preparation of concrete mixture with the proposed OMA differed from the initial one in that instead of a part of cement consumption the corresponding amount of preliminary crushed ash-and-slag waste of Novocherkasskaya thermoelectric power station was introduced into the mixer.

In developing and optimizing the composition of OMA on the basis of the studied source materials it was necessary to identify the optimum fineness of ash and slag composition, characterized by the value of specific surface area (S, cm^2/g). It is also necessary to establish the maximum possible value of replacement of cement in the initial composition of the concrete mixture with the proposed OMA without loss of concrete strength.

Subject matter and problems of the research

Ash-and-slag wastes of thermal power stations are formed at combustion of pulverised solid fuel in furnaces of boiler units. At Novocherkasskaya thermoelectric power station fine grinded hard coal from the Donetsk coal basin is used.

The removal of ash and slag to the dumps is done hydraulically. In this process ash and slag are usually mixed in slurry pipelines and transported to special ash and slag dumps.

During the exploitation of Novocherkasskaya thermoelectric power station, one of the largest in Europe, more than 40 million tons of ash and slag wastes have accumulated.

Considering the huge resources of ash and slag waste in the dumps, expanding their use for practical purposes is of great environmental and economic importance.

So, the task of this research was to experimentally study the possibility of obtaining OMA on the basis of

waste ash and slag waste, providing a reduction in cement consumption without loss of concrete strength.

To decide the problem we used methods of the theory of planning experiments. These methods allow us to find optimal solutions in the study of complex systems under statistical indeterminacy.

By setting up experiments according to one or another mathematical plan of experiment, the corresponding statistical processing of experimental data allows to obtain a polynomial model of the studied dependence in general form:

$$y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{ii=1}^{m} b_{ii} x_{ii}^2 + \sum_{ij=1}^{k} b_{ij} x_i x_j, \quad (1)$$

where:

- y - the response function under study,
- x_i, x_j - coded values of the i-th and j-th factors,
- b_i - required coefficient of the i-th factor,
- x_{ii}^2 - quadratic term of equation (1) for the i-th factor
- b_{ii} - required coefficient of the quadratic factor i,
- $x_i x_j$ - interaction effect of the i-th and j-th factors,
- b_{ij} - the required coefficient of the interaction effect of the factors.

In this study, the response function y for model (1) was the relative strength of the concrete:

$$y = \frac{R^{28}i}{R^{28}_{contr}} \cdot 100 . \quad (2)$$

The influencing factors on the strength of concrete with the OMA were taken:

X1 - a part of cement consumption reduced due to the corresponding amount of OMA introduced into concrete composition in the range of 5-25 % ,

X2 - a degree of ash and slag dispersion characterized by specific surface value (S) in the range of S = 2000 - 4000 cm^2/g.

For mathematical modelling of concrete strength dependence on research factors $y = f(X1, X2)$ a modelling Box and Wilson's second-order plan on a regular hexagon [10] was used, which allows to obtain a quadratic model of the system under research by the results of 7 experiments.

Results and Discussion

The planning matrix and the results of the experiment are presented in the Table.

Table. Planning and results of the experiment

№	Plan		Analysis Matrix			Result $y = \frac{R^{28}i}{R^{28}_{contr}} \cdot 100$, %
	X1	X2	X1 X2	X12	X22	
1	- 0.5	- 0.87	0.43	0.25	0.75	90
2	0.5	- 0.87	- 0.43	0.25	0.75	87
3	- 1	0	0	1	0	114
4	0	0	0	0	0	101
5	1	0	0	1	0	90
6	- 0.5	0.87	- 0.43	0.25	0.75	110
7	0.5	0.87	0.43	0.25	0.75	100
$\sum_{i=1}^{7}$	(1y) - 30.5	(2y) 28.7	(12y) - 3.0	(11y) 300.75	(22y) 290.25	(0y) 692

The realisation of the experimental plan presented in the Table allows to calculate the unknown coefficients of the polynomial model (1), which for two factors in our casework has the form:

$$y = 101 - 10.2x_1 + 9.6x_2 - 4x_1x_2 - 6x_1^2 + x_2^2 \, . \quad (3)$$

Model (3) mathematically describes a response surface in the factor spectrum under research. For interpretation of the new function, a geometric image of the response surface under study is constructed.

The Figure presents the geometrical image of the researched response surface in the form of isolines (lines of equal output) on the factor plane (similar to the way mountains or sea hollows are depicted on the geographical maps).

Analysis of the geometric image of the obtained mathematical model (shaded area of the Fig.) demonstrates that the introduction of the developed OMA in an amount from 8 to 18 percent of the volume of cement provides its saving without loss of concrete strength.

In this case, the higher the grinding degree of ash-and-slag waste is, the greater the cement saving is.

However, increase in grinding fineness increase energy consumption and reduces the effectiveness of grinding equipment.

Therefore, the choice of the optimal degree of ash-and-slag waste grinding is determined by technical and economic calculation, considering the specifics of local conditions.

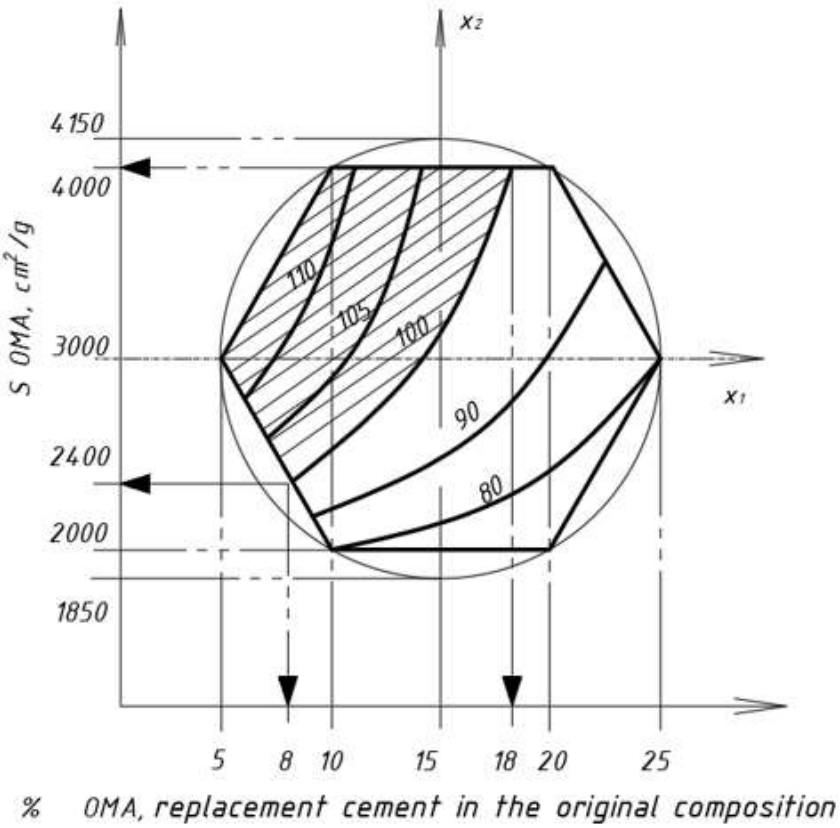

Fig. *Geometric image of the response function* $y = \frac{R^{28}i}{R^{28}_{contr}} \cdot 100$, %

Conclusion

The effective complex organomineral additive using ash and slag wastes as a mineral component has been developed. The total amount of ash and slag wastes at Novocherkasskaya thermoelectric power station exceeds 40 million tons and their use solves economical and ecological problems.

The methods of experiment planning theory made it possible to obtain a mathematical model and design its geometrical image. Integration of which allows, depending on the degree of ash-and-slag waste grinding and the consumption of the recommended admixture, to reduce cement consumption by 8-18% without loss of concrete strength.

It is advisable to use the methodology of the solution of this problem in further research aimed at expanding the nomenclature of organomineral additives based on waste products of sedimentary (limestone-slags, opoka, etc.) and volcanic rocks (tufa, perlite, pumice, etc.), which are local raw materials in the region.

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THE FORMATION OF REGIONAL IDENTITY INVOLVES A VARIETY OF DIFFERENT POWER RELATIONS (CASE STUDY: COASTAL AREA, SEDATI DISTRICT, SIDOARJO REGENCY)

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Abstract: *Currently, Sedati Regency's coastal region has undergone an identity shift. The region, which was once renowned as a representation of seaside culture, has been changed into a new official residential community at the beginning of new operations in 2018, such as the massive construction of formal settlement sites. In an effort to establish a new identity, each of these operations maintained control over coastal regions. By employing power relations analysis approaches, such as archeology and genealogy, to uncover local behavior, which in turn can establish regional identity, qualitative research techniques and data analysis can be used. According to Focault's analysis, the identity of the coastal region is changing, and the local Javanese and Madurese cultures are having an impact on the power dynamics in informal dwellings. Meanwhile, because the majority of inhabitants are diverse immigrants, power dynamics in formal housing are shaped by urban culture.*

Keywords: *Coastal culture, Power relations, Informal settlement, Formal settlement.*

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Introduction

One of the Sidoarjo Regency's subdistricts, Sedati's land is characterized by coastal regions. Since Sidoarjo's coastal area is equivalent to one that is still heavily influenced by coastal culture, the coastal area is another place that receives a lot of tourist traffic. The interaction between traditions, such as riverfront tourism, Nyadran, Reog Cemandi, and Banjar Kemuning Dance, ensures that coastal culture is still preserved. [1]. A city's coastal area is its beach or coastline, which is a vibrant and distinctive location [2].

The quantity of visitors and increasing tourist awareness are both indicators that coastal culture is currently developing. There are various activities that promote seaside culture in addition to the numerous tourist trips. In order to increase public awareness of coastal culture, the sub-district frequently organizes promotion events in partnership with the commercial sector or academies. There is a lot of marine potential. Along with the normal coastal scenery, there is a milkfish manufacturing facility that is expanding quickly. With such natural and cultural potential, Sedati regency might use this as a tourism destination to raise the standard of living of its residents [3].

The end of the 2019s saw a number of fresh developments, including the growth of numerous legal settlements. Former freshwater fish ponds now appear to be home to formal towns. The introduction of formal settlements altered the visual character of the coastal region, transforming it from an unorganized, mostly homogeneous informal settlement area for fishing into a formal settlement area that is ordered and tends to be.

Formal settlements are continually being built, and this leads to new activities and new architectural styles. One of the attempts to demonstrate self-actualization so that identity and social standing may be maintained is the formation of activities and new visual personalities [4]. The annual activities are a means of self-actualization for the coastal region, much like the coastal culture itself, which has taken on a distinctive regional identity.

Power relations are seen as a necessary component of self-actualization. Although it cannot be seen with the naked eye, power is a social phenomena that can nevertheless be felt. The need of humans to have shelter that interacts with their surroundings gives rise to the impact of power [4]. Both identities come into existence

as a result of the constantly shifting influence of power. However, the town has continued to keep and protect its identity as a seaside region of relations, therefore it still exists today.

Methods

The qualitative research approach uses a combination of data collection tools and the researcher as the main instrument to investigate the condition of natural things. It is founded on the postpositivist school of thought [5].

While employing a qualitative method based on power relations, such as genealogy and archeology, the data analysis method leverages these techniques. Foucault examines the connection between knowledge and power through genealogy and archeology. In Foucault's view, genealogy is an attempt to get away from the rulers' historical knowledge in order to be able to resist and deal with compulsion that is general and abstract in character. Genealogy provides a lens through which to see and analyze epistemology, social activity, and the nature of the human self [6].

While Foucaoult [6] views the archaeological technique as the investigation of certain actual and precise historical circumstances, with diverse claims to be united in order to identify distinct knowledge and need particular pairs of concepts.

Result and Discussion

Shifting the identity of space as a representation of power

The social, cultural, economic, and architectural characteristics of the coastal area make it distinct from the coastal culture. Instead of in more varied urban areas, a coastal culture that embodies the livelihood of fishermen and trade becomes the identity of the area. The capacity to distinguish and recognize elements from one another is related to identity. Shape, size, ornamentation, and other aspects of the surroundings all contribute to identity, though under different circumstances [7].

Sedati's seaside region is seeing a growth in culture and is quickly rising to prominence as a top travel destination in the Sidoarjo Regency. The architecture is likewise impacted by these changes. The spatial organization of architecture can affect and direct user behavior. Sign, coding, channelization, and their interrelationships all have an impact on these processes. So that there will be chances for people to use the area that we construct [8]. Architecture can be viewed in terms of power dynamics as power that is stimulated by its form. On the other hand, the architect contributes to the power that creates space, preventing neutral space from ever existing. The power relations that are an element of coastal architecture.

As a result, both the physical and non-physical aspects of regional identity are always linked to power dynamics that are discernible from social, economic, and political contexts.

Architecture and society are now understood as a production process rather than as a relationship of expression or representation. Consequently, in power interactions, both architecture and people are both objects and subjects. According to Foucault's theory, knowledge creates the effects of power while, on the other hand, power develops and gives rise to new objects of knowledge [9]. From this perspective, Foucault asserts that power is no longer just oppressive and confining but also more positive and productive [10].

Occupancy in Informal Settlements

Original settlements on the Sedati coast are informal communities in coastal locations. Native Javanese and immigrants, notably the Madurese, coexist in this informal town, resulting in the acculturation of the two cultures [11].

The material, form, and purpose of a space all reflect the influence of coastal culture on architecture. On the shore of Sedati Sidorjo, fishermen's homes typically have a big terrace where they can store both their fishing gear and their catch. Along with fishing, many residents of the coastal region are pond farmers (milkfish and shrimp), who share the same typology - namely, a sizable terrace used to house aquaculture farming equipment.

Observed that in a certain setting, power tends to persons or subjects. It will be challenging to distribute power to social networks because power tends to go to the person [12]. The public awareness network is where this power operates subconsciously. A representation of strength is the coastal region of Sedati, which is synonymous with coastal culture that has been passed down from generation to generation and whose traditions are still upheld today. The architecture of informal communities in Sedati's coastline region reflects the blending of Javanese and Madurese traditions (Fig. 1).

Fig. 1. *Informal settlements in the Coastal area*

Residential analysis

The terrace serves a variety of purposes in informal communities along the shore, including economic, cultural, and social ones in addition to serving as a place to wait before entering the house. The principles of the Javanese and Madurese philosophy of life based on the Genealogical analysis method have an impact on the variety of terrace functions. The model of the terrace of the house in the coastal informal settlement with the religious function is analyzed using the archaeological approach (Table 1).

Formal housing development

In the early 2019s, formal residential zones began to develop along the coast. The visual appeal of the region and the social climate of the neighborhood are also impacted by the growth of new official settlements. This formal settlement came about as a result of the Sidoarjo Regency Government's strategy, which was outlined in Regional Regulation No. 6 of 2009, which limited settlement efforts to about 40% of the overall land[1] (Fig. 2).

Later forward, the Sedati Coast will develop into a coastal tourist destination and a populated area. in order to coincide with the growth of coastal tourism and the establishment of new official towns.

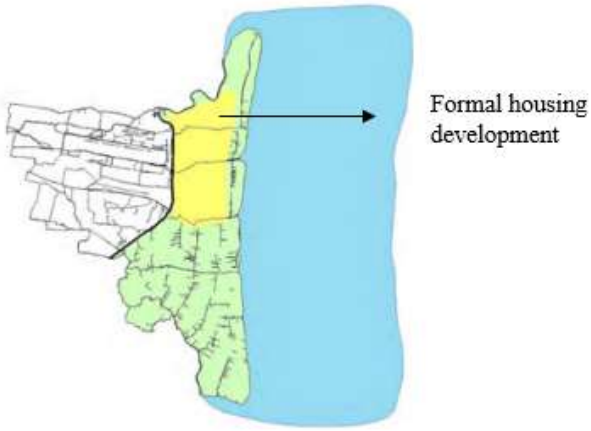


Fig. 2. *Formal housing development*

So since the coast of Sedati is starting to change its purpose into a formal residential area and tourist, it is no longer just known as a coastal location that is synonymous with coastal culture. Power relationships will always alter since they are not static. The creation of a new identity as an area of informal settlement is a startling change in the coastal region (Table 2, Fig. 3).

Fig. 3. *Formal housing development*

[1] Perda Sidoarjo. 2009

Table 1. Analysis of power relations in informal settlements on the coastal area in Sidoarjo

No	Architecture	Space	Function	Social and culture	Activity	Genealogical Methode	Archeological Methode
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1.	Settlement	Terrace	Storage Space	Personal Relationship	Used to store fishing equipment	The terrace being used as a place to keep fishing gear. Because the Javanese and Madurese have a life philosophy of reverence for environment, they make a living as fishermen. Both the Javanese (*Hamemayu Hayuningbawana*) and the Madurese (*abhantal omba 'asapo' angen*) have words that refer to enhancing the world's beauty and how tenacious and persistent they are in overcoming even the most difficult circumstances. The livelihoods, customs, and environmental factors all have an impact on the exhibition space. The Javanese and Madurese are the tribes that live in Sedati's coastline region. Javanese people with a strong life philosophy *Towuh Wiji ing Sela* (seeds that grow in stone) work hard to achieve success. The Madurese have a philosophy of life that describes how their souls evolve from the perspective of financial well-being as a means of achieving psychological well-being [13].	The use of terraces in coastal areas is mostly used as fish storage space and fishing equipment storage. So it requires a large space by utilizing a simple construction. 
			Display Room		Along with being fishermen, the people of Sedati's coastal region also work as traders. Seafood and marine items are available in the coastal region (Continued: Milkfish remove thorns; also, milkfish, seafood, etc.)		
			Social space	Social Relationship	Recitation Socializing with neighbors while waiting for husband to come home from fishing	Because it is influenced by customs and practices practiced by coastal populations (Javanese (*Manunggaling Kawula lan Gust*i) and Madurese (*li'bali'na dhadhar*), who also have a philosophy of life, human relations with God, and recitation, space is utilized as a space for socializing and recitation. with people (social)	Terraces are typically used as a place for recitation and social interaction in coastal settings. These activities take place frequently and call for a sizable area for socializing.  Terrace

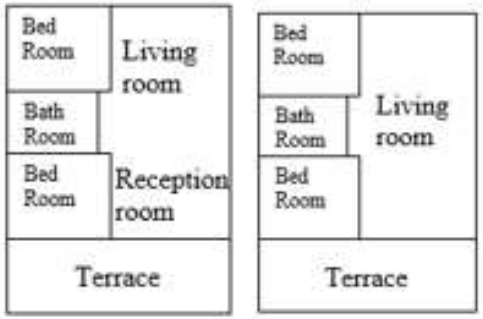
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
		Indoor space	A place to rest and gather with family	Social Relationship	Rest Gathering with family	Using the area as a location to relax and spend time with family as a personal area that only homeowners have access to. Their customs and beliefs have an impact on access limits as well. Access restrictions are also influenced by their traditions and beliefs.	The indoor space in coastal communities is identical to simple spaces. - Terrace-r family-bedroom-bathroom - Terrace-r guest-r family-bedroom-bathroom 
		Vernacular Architecture				Gable-roofed, traditional buildings make up the majority of the housing stock in coastal communities. When it comes to thermal comfort, using a high roof makes it easier for air to circulate on the roof. The cultural perspective, which is an expression of the nature of appreciation of the life and beliefs of its people, is seen in addition to the scientific perspective [8].	The distinctive features of traditional residential buildings in coastal regions, particularly in Java, include tile-covered gable roofs, timber exteriors, and exposed bricks [14]
		The materials used are wood and bricks for the construction of the walls				The use of wood is a component of the *Hamemayu Hayuningbawana (*Java) and *abhantal omba "asapo" angen* (Madura) concepts, which maximize the environment.	Wood is used in the construction because it is a cheap, simple material to deal with, and it is also simple to find the proficiency of nearby workers in wood construction.
						The use of space as a social gathering place (*Rukun agawe santoso*) coffee and gunong (Madura). The customs and practices practiced by coastal populations have an impact on the recitation.	

Table 2. Analysis of power relations in formal settlements on the coastal area in Sidoarjo

No	Architecture	Space	Function	Social and culture	Activity	Genealogical Methode	Archeological Methode
1.	Home	Terrace	Storage Space	Personal relationship	Garage and social space	Using the terrace as a garage and storage area for vehicles. A vehicle is necessary to facilitate the urban lifestyle's high level of movement.	Terraces are typically utilized as a garage and a place to store things in formal settlements 
			Social Space	Social Relationship	Transition space	The behaviors of urban dwellers, who discourage interaction with the surrounding area, have an impact on how space is used as a social and transitional place.	The construction of barriers to prevent residents from mingling with one another. 
		Indoor space	Social Space	Social relations with family members	Rest Gathering with family	The developer has chosen the inner space's style and specifications. Residents who desire to experiment with processing space also contribute to the development of inner space because it is influenced by the way of life and habits of the occupants.	The state of an interior space that aims to be able to maximize it for the demands of the occupants.  
		Form	Architecture Contemporer			In formal settlements, the developer decides the design of the house, which is largely dictated by business and market considerations, making it impossible for homeowners to decide the ideal shape.	Houses in official communities generally have the same shape while being in different places. Because it relates to the developer's budget, the shape that is highlighted is more on a form with minimum decoration.
			The materials used are wood and bricks for the construction of the walls			The chosen material is one that is easily accessible on the market. Price is another factor that developers take into account when choosing materials, in addition to availability. The development of accessible styles on social media has an impact on the trend of utilising materials.	The material picked is one that is frequently utilized for official residential structures. The final shape will be relatively the same because the materials chosen and the volume that has also been established are both relatively the same.

Conclusion

According to the study's findings, power relationships that have developed in informal settlements (original settlements in coastal areas) through genealogical and archaeological methods are influenced by the two ethnic groups' different life philosophy, and regional identity is made up of both physical and non-physical aspects (Javanese and Madurese). Its design symbolizes the way of life that governs how people connect with God, other people, the environment, and themselves. Their actions and surrounding architecture are a reflection of the lifestyle they follow. Meanwhile, archaeological research explains why informal communities have a variety of appearances but often the same architectural traits (material, construction, and use of space).

According to genealogical studies, the majority of people in formal settlements have varied ethnic roots and are immigrants rather than natives; nonetheless, the developer, who holds the regional identity that promotes capitalist interests, has an influence on the region's identity. The developer establishes the types of rooms and activities. On the other hand, existing formal settlements in coastal areas have the same form, material, and construction system based on archaeological studies since they adhere to the developer's criteria. In coastal communities with informal settlements, the idea of homogeneity serves as a sort of identity.

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METHODS FOR THE FORMATION OF ENERGY-EFFICIENT ARCHITECTURE OF SOCIAL OBJECTS IN WORLD DESIGN PRACTICE

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Abstract: *Today, people are increasingly drifting away from nature in an age of accelerated lives and information technology. Only the natural environment can create comfortable, ecological conditions for human life. It has become evident that the biological component of the domain has been noticeably reduced in the big cities, and the appeal to the global architectural community of the ecological and aesthetic aspects of design and construction, which contribute to the comfortable and sustainable development of urban space, has become particularly relevant over the past decades. In a big city, architecture is omnipresent. Hence, the architectural-spatial environment should be solved as much as possible in the context of the natural environment, embodying not only the material needs of a person but also spiritual ones. The current unfavorable environmental, energy, and economic situation in the world requires new methods for designing and building the architecture of new and reconstructed old buildings. The article discusses the issues surrounding the formation of modern energy-efficient architecture in the context of its relationship with the natural environment through the use of modern design solutions. The article is based on surveys of social facilities made by the authors from 2017 to 2021 in Eurasian and European cities. The article analyzes a new mechanism of architectural formation based on the shape formation of an architectural object, the content of the architectural shape, the aesthetics of perception, and the organization of eco-space.*

Keywords: *architecture, social facilities, energy efficiency, world experience.*

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Introduction

In the middle of the twentieth century, the world's major cities faced solutions to serious environmental problems, the prerequisites for which were economic growth, urbanization, and urban population growth. The city is a complex organism, representing the close interaction of objects created by humans for socio-cultural, domestic, and industrial purposes with the components of the natural environment. With the urban areas' expansion and development, this interaction assumes the form of the growing pressure of urban area development on the environment.

In today's world, urbanization issues have long been at the forefront of the fight against urban pollution. The problem stems from humanity's focus on boosting economic development, increasing yields, and increasing productive values. However, the protection of the environment in urban development, as well as in the development of infrastructure, is ignored [1].

The high concentration of various types of human activity, while creating several unconditional advantages, nevertheless led to a disturbance of the optimal balance between the natural and artificial components of the landscape. As we approach the tipping point where the deterioration of the biosphere becomes uncontrollable, cities face an urgent need to preserve and maximize the natural components of the environment [2].

Nevertheless, "only in the city, being a product of civilization, a person can satisfy his needs in labor and creative work, in spiritual and cultural spheres, in education and development of the intellect, in wide communication and social movements, in fascinating spectacles and pleasures, in sports and mass relaxation" [3].

As public awareness of the magnitude of the anthropogenic load on the environment grew in the 1960s and 1970s, the global architectural community investigated various approaches. New scientific developments in this direction are being developed. Several studies have been conducted on many aspects of urban ecological development. The issues of climate change due to human activity are revealed in A.I. Voyvekov's and M.I. Butko's research. In J.E. Aronin's research [4], special attention was paid to the influence of climate and its elements on architecture. Here, the author emphasizes that "the peculiarities of the regional climate and local weather conditions are the first basis for the formation of ecologically sustainable urban systems" [3].

In the concept of the city's ecologization, Tetior A.N. describes the importance of preserving and restoring the natural environment. Additionally, ecological buildings must address the challenges of self-sufficiency and recycling through innovative, architectural, and technological solutions. Moreover, "green" buildings should be able to restore nature [2].

Ecological and urban development of cities, their sustainable development in V.A. Kolesnikov's research. From the standpoint of philosophy, Ilvitskaya S.V. and Lobkova T.V. [5] investigate the relationship between housing architecture and the natural environment, whereas Belyaeva E.L. [6] investigates the problem of visual perception of the architectural environment. Karpov S.V., in his scientific article on the basis of modern foreign materials, considers problems of urban ecology in the context of the ethical and aesthetic aspects of architecture [7].

The work's novelty is to develop new methods for creating a modern architecture of social facilities based on human interaction with the environment, considering regional conditions. This study aims to scientifically substantiate the methods of energy-efficient solutions to the objects being studied in architecture and to propose them for use in designing buildings. Based on the goals set, the research objectives are defined as follows: study and analysis of foreign and domestic experiences in creating energy-efficient architecture; development of the method's structure for the formation of energy-efficient architecture.

Materials and Methods

The authors conducted a full-scale study of the architecture of social objects in Astana, Yerevan, Delft, Copenhagen, and Groningen. The research material was formed based on a scientific program and internships in the framework of improving the quality of education in the training of architects. From the list of studied buildings, the authors have selected objects where the subject of the work is most clearly expressed. These are modern buildings built in cities such as Astana, Yerevan, Delft, Groningen, and Copenhagen.

The analysis method and investigation of the objects under study allowed to identify four main aspects of the architecture's relationship with the natural environment, which, according to the authors, determined the principles of the formation of energy-efficient architecture and are the basics for solving the modern city's environmental problems.

Results and Discussion

Having studied architectural objects, the authors described the main methods of formation that contribute to reducing the ecological load on the urban environment, i.e., shape formation, principles of natural structures in architecture, mimicry of the architectural environment, and visual perception of architecture and the architectural environment. In turn, the methods should be separated into two primary categories: morphological (shape formation, principles of natural structures in architecture) and aesthetic (mimicry of the architectural environment, visual perception of architecture).

Shape formation

Over the past decades, a definite paradigm has developed in architectural theory and practice for understanding and developing the architectural shape formation of objects, which is based on natural processes. The problems of urban ecology and the relevance of natural factors predetermined the appeal of the natural forms of living organisms and their associative image in architecture. The volumetric and spatial possibilities of architecture, with the involvement of the morphological aspect, contribute to the formation of a harmonious, light, durable, ecological, comfortable, and energy-saving architectural environment.

Natural structure construction principles in architecture

Wildlife is not only the most beautiful form of life, but it is also a superb example of an architectural structure, combining many structural systems in a more effective way.

For example, spider threads, which have high strength, form the basis of cable-stayed structures. Twisted, spiraling structural forms (borrowed from the twisting shape of shells and the spiraling of the stem of a plant, etc.) are used in the architecture of high-rise buildings or spiral central staircases. The cereal plants' spindle-shaped stem is a prototype of the elastic hinge-damper device in buildings, which, in turn, can withstand strong wind flow. The prototype for structure formation in architecture was various perforated structures of deep-sea living organisms. For example, the basis of the artistic idea of a bike-pedestrian bridge in Astana is the form of a sturgeon fish.

A vivid example of nature symbolism is the sculptural composition of the Grand Cascade public space in Yerevan: Alexander Tamanian's sculptural composition and Derenik Danielyan's mosaic panel sculpture (unfortunately not preserved).

Mimicry of the architectural environment

Each single energy-efficient building cannot solve the ecological problems of the urban environment. The main task of architectural and urban mimicry is the "co-scale reappearance of natural objects", i.e. immersion of a person into the natural environment. Such objects become aesthetic "green" centers of attraction in a highly urban environment [8].

Planting green spaces in areas characterized by a strong breeze also creates a barrier to wind flows, forming a more comfortable zone - an "aerodynamic shadow".

Thus, the object becomes the center of gravity, where the reason for gravity is the person's simple needs: to breathe clean air, contemplate and walk, and immerse in the natural environment (Fig. 1).

Architectural objects: 1. Sculptural composition of the Grand Cascade and mosaic panel (Armenia, Yerevan) and archival photo of A. Danielyan's mosaic panel, 2. Dormitory (Copenhagen, Denmark), 3. The Bike and Pedestrian Bridge (Kazakhstan, Astana), 4. The central staircase in the Palace of Schoolchildren (Kazakhstan, Astana), 5. Interior of the academic building of the Groningen Technological University Hanse (Netherlands, Groningen), 6. Copenhagen International School (Copenhagen, Denmark), 7. A. Tamanyan's Grand Cascade (Armenia, Yerevan) - photo by A. Toyshiyeva, 8. Walden Dos School, Mexico City, 9. The interior of the mockup workshop of the *Faculty of Architecture* and the Built Environment at *TU Delft* (Netherlands, Delft) - photo by A. Toyshiyeva.

Fig. 1. *Methods of energy-efficient architecture: shape formation and mimicry of the architectural environment*

Visual perception

An essential point for understanding architecture is its visual perception of personification, which is based on various methods of aesthetic expression. To create an expressive, comfortable urban environment using compositional-aesthetic means and the texture of the materials used, such as metric organization and rhythm; the texture and color of the materials used; bright color accents of facade finishing elements; artistic techniques for using natural and artificial light (for example, for visual comfort, the use of light at night); preservation of the natural landscape, the use of natural materials and alternative energy sources, the use of green roofs, planting of greenery. For the reconstructed building color formation or site development in general, it is vital to make a decision in the context of the color image of the natural and architectural environment.

In light of criticizing the globalization of urbanism and urban development without considering the local peculiarities of the territory, the most logical approach is one based on the territory's traditional structures with new functionality and technological improvements. The identity of urban space lies not only in traditional architectural forms but also in geometric and human-scale configurations of space and aspects of the citizen's interaction with this space [9].

The peculiarities of natural structure construction and various means of aesthetic perception can be traced back to the implemented and studied objects of energy-efficient architecture (Fig. 2).

Architectural objects: 1. Smooth fishlike shape: a perforated structure in a bike-pedestrian bridge (Kazakhstan, Astana), 2. Principle of spiral: The central staircase in the Palace of Schoolchildren (Kazakhstan, Astana), 3. Grid principle: Copenhagen International School (Copenhagen, Denmark), 4. The principle of the web-supported cable-stayed structure in the Khan-Shatyr shopping center (Kazakhstan, Astana), 5. The principle of the leaf vein grid, interior of the academic building of *Hanze Institute* of Technology (Netherlands, Groningen), 6. Texture and color of finishing materials: Schoolchildren's Palace (Kazakhstan, Astana), 7. Artistic technique of using natural light: the central hall in the interior of the Schoolchildren's Palace (Kazakhstan, Astana), 8. Artistic technique of using artificial light: SEC Khan-Shatyr (Kazakhstan, Astana), 9. Walden Dos School, Mexico City, 10. Copenhagen International School (Copenhagen, Denmark), 11. The central staircase-tribune of the Faculty of Architecture of the Delft University of Technology (Netherlands, Delft).

Fig. 2. *Energy Efficient Architecture Methods: Natural Designs in Architecture, Visual Perception*

Conclusion

An analysis of the methods for forming an energy-efficient architecture, in addition to the basic principles and design standards, makes it possible to identify principles aimed at improving the quality of the environment.

The fundamental principles of the morphological method of formation are determined by an associative way of natural forms and processes in architecture:

- the personification of natural forms in architecture (the principle of a fish, a circle, a spiral, nature symbolism in public space details and facade decoration),
- the personification of natural structures in architecture (the principle of a spiral, cobweb, grid, perforated structures).

The fundamental principles of architecture and visual perception are the ideals of organizing life:

- the submission of the shape of building and the public spaces to the relief,
- spatial connection of the interior with the natural environment,
- access to light and clean air,
- means of expression through metric organization and rhythm, the color of materials, bright color accents of facade elements, artistic methods of using natural and artificial light, using natural materials, using green roofs.

Today, in a period of high technological development and increasing societal dynamics, new methods of architectural design are becoming increasingly relevant, where architecture promotes the establishment of harmonious relationships between humans and the external world and determines the organization of adaptive, comfortable space in relation to contradictory sociocultural processes occurring in society. As a result, architectural creativity in the twenty-first century is determined by a new vector toward the creation of comfortable surroundings, i.e., the symbiosis of architecture and nature, the symbiosis of various cultures, and the symbiosis of the historical past and the future.

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SEPARATE PRINCIPLES OF SPATIAL PLANNING IN THE BORDER REGIONS ON THE EXAMPLE OF MEGHRI COMMUNITY

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Abstract: *The paper aims to apply such principles of territorial planning in border areas and regions under the threat of war, which will allow to meet the primary needs of the population under relatively peaceful conditions and, in emergency situations, will reduce the vulnerability of territories and populations. To solve this problem, the issues specific to the border regions and principles of their classification were studied, which were found both in international documents and in scientific publications. In the example of the Meghri community of Syunik Marz, RA, such factors directly related to spatial planning, such as geographical location; natural, economic, and cultural resources; territorial placement of settlements; population; and infrastructure, were investigated. To solve the problem of access to public services, the infrastructures for providing the primary needs of the population were selected and categorized according to access levels. The study's findings led to recommendations for using these spatial planning concepts, which will guarantee that all the residents in the community's settlements have access to services.*

Keywords: *border region, settlement, security, road network, infrastructures, access to services.*

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Introduction

There are references to the issues of border regions and ways to solve them both in documents adopted by various international organizations and in scientific publications. The official documents touch upon issues related to interstate relations as demarcation, delimitation, and recommendations for solving related problems[1], the political and legal responsibility of states for border security and border regime issues, international standards of human rights, particularly of refugees, free movement of people, goods, services, and investments, terrorism prevention, economic cooperation in border zones[2], regulation of cargo transportation on borders by land, air, and waterways[3], etc.

The frameworks of the studies related to the problem are broad and diverse. They can refer to the formulation and interpretation of the term “border” itself (Boundaries, Borders, Frontiers), the historical and geopolitical features of their formation [1], the origin and consequences of borders [2], and the reasons for the border formation and changes between the empires and states in different historical periods [3], the opportunities and limitations of border regions [4], the state policies and investment directions related to their development [5], problems of infrastructure placement in border cities [6], people’s perception the problems, and the classification of borders as a gap and as a communication opportunity based on interactions [7,8].

However, if we try to generalize the different provisions made in official and scientific publications on border regions, we should note that the main border-related issues are determined at the level of relations

[1] Delimitatsiya i demarkatsiya gosudarstvennykh granits: aktual'nyye voprosy i sposoby ikh resheniya.The Organization for Security and Co-operation in Europe, 2017 (in Russian). https://www.osce.org/files/f/ documents/2/ 8/363471.pdf

[2] Konventsiya v oblasti bezopasnosti granits i pogranichnogo rezhima. The Organization for Security and Co-operation in Europe, 2005 (in Russian). https://www.osce.org/files/f/documents/a/6/70205.pdf

[3] Mezhdunarodnaya konventsiya o soglasovanii usloviy provedeniya kontrolya gruzov na granitsakh. United Nations, 1982 (in Russian).

between bordering countries. Accordingly, scientific publications are dominated by the classification principles put forward by Van der Velde and Martin [7] back in 1997, according to which border regions can be:

- separated from each other (alienated) because of military operations, political, religious, cultural, ethnic, and other conflicts,
- coexisting with a certain economic and cultural contact,
- interconnected, with as much full cooperation in the economic, social, and cultural spheres as is possible in the case of functioning borders,
- integrated - with the free movement of people, goods, investment flows, and ideas.

Leaving aside the last three options, we should note that the isolated regions had different manifestations in different historical periods, from Hadrian's Wall and the Great Wall of China to the Berlin Wall and the "Trump" wall built between the United States and Mexico. The main problems were the protection from tyranny, the security of the state or populations in border regions, as well as restrictions on the movement of people. However, regarding frozen conflicts and hostilities, we are dealing with either the concept of "border" in its accepted meaning, but "floating" borders, or more accurately, contact lines, which can shift regularly and endanger the security of the people living in the border regions.

Similar manifestations continue to exist in various parts of the world (Syria, Palestine, Israel, Eastern Ukraine, Central Asia, South Caucasus, etc.), causing constant tension among the residents of border regions, disrupting normal life activities, obstructing economic development, and, in some cases, causing humanitarian disasters. Studies on specific issues of border regions are also published in Armenian scientific publications [9,10,11], but there are no studies on the principles of spatial planning - concerning population security.

States typically use the civil or "passive" protection toolkit, which includes the placement of shelters in structures for various purposes, lighting, rapid response systems, rescue operations, population evacuation, and first aid measures to ensure the normal life of the population in the regions under the constant threat of war. These measures are necessary and may somewhat reduce the level of vulnerability of territories and populations, especially during the hostilities.

Decent living standards in peaceful circumstances and the development of a system of public services that will give the populace some level of confidence in the future, however, are incredibly vital in the regions in question for preventing the inevitable pattern of emigration in such circumstances.

This paper assesses the problems of urban development factors affecting people's safety in war-prone areas, considers the characteristics of the territorial distribution of the network of settlements and infrastructures, and develops such principles of mutual connections and relations, which will ensure the availability of services for residents of all settlements in relatively peaceful conditions, and during operations will reduce the level of vulnerability of territories and the population, creating prerequisites for ensuring an adequate quality of life in these regions.

The study was conducted on the example of the realities that have been developed in the Meghri region in the south of the Republic of Armenia as a result of the 44-day war unleashed by the Republic of Azerbaijan in 2020.

The following aspects essential to the area were examined and assessed to meet the study's goal:

1. the geographical location, natural, economic and cultural potential,
2. inter-settlement relations, especially the territorial settlement and population,
3. existing infrastructure for the provision of public services and their distribution in the human settlements network.

Administrative and topographic maps of the region, the Meghri community website, and information provided to the author by community staff regarding the existing infrastructures in the community were used for the study.

Materials and Methods

General information about the region

In Soviet times, Meghri was the center of an eponymous administrative district. During the independence in 1995, 13 self-governing units (communities) were formed here[4]. In 2016, within the framework of the community consolidation program in the region, one community was formed in the center of Meghri, which included 15 settlements[5].

The community's population is 11.769, and over 80 percent of the population lives in Meghri and Agarak. The administrative area is 659.9 square kilometers[6].

Geographical location

Meghri region has exceptional geopolitical and strategic position, that is why it has been subjected to various conquests in different historical periods.

The region is not only a crossroads of important north-south and east-west infrastructures, but also an island that remains in proximity to transboundary regions with different historical, religious, and cultural values (Fig. 1).

It borders with the Islamic Republic of Iran from the south along Araks River, with the Republic of Azerbaijan from the east and with the Nakhichevan Autonomous Republic, which is part of the Republic of Azerbaijan and does not have a common border with it from the west (why this region became part of the Republic of Azerbaijan is a question of research in another area - let's say that in 1915 the number of Armenians in the Nakhichevan region was 55572[7], in 1926 - 11276[8], in 1989 - 1858[9], in 2009 - 6[10]).

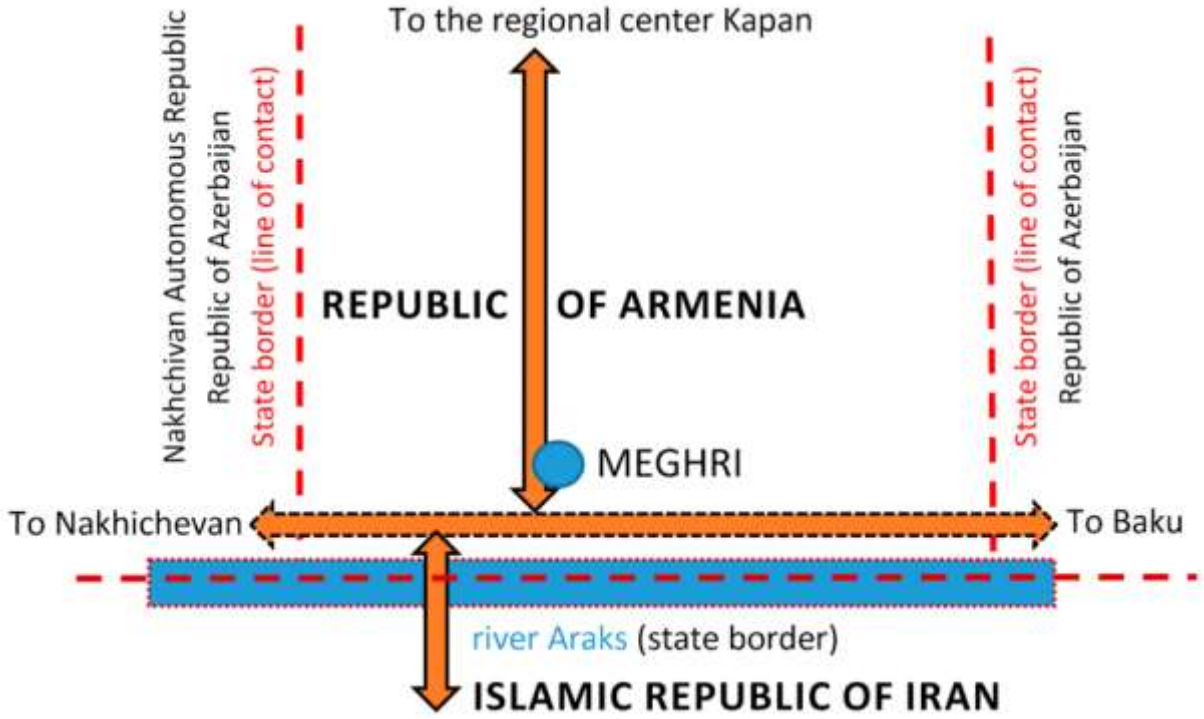

Fig. 1. *Geographical location of the Meghri community*

[4] Bulletin of the National Assembly of the Republic of Armenia, 9, 1995.
[5] Official Bulletin of the Republic of Armenia 2016.07.01/51(1231) (in Armenian).
[6] Meghri Municipality. https://www.meghri.am/
[7] Caucasian calendar for 1916 . https://www.prlib.ru/item/417321
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[10] http://pop-stat.mashke.org/azerbaijan-ethnic2009.htm

We can point out that Meghri serves as the single land connection between the Republic of Armenia and the Islamic Republic of Iran and generally with the outside world. The roads and railways in east - west direction have not been in operation since the Artsakh-Azerbaijani conflict began.

The Zangezour mountains dominate the region's western part, while the Meghri mountains dominate the northern and northeastern parts. The lowest point (374 meters above sea level) is in the eastern part of the state border on the river Araks, and the highest is the Parakan (Sisakapar) top of the Zangezur mountains (3826 meters above sea level), which speaks of different landscape and climatic manifestations on this small area, from dry subtropical to cold mountains[11].

Economic, natural and cultural potential

This region has both metallic (gold, molybdenum, copper, iron) and non-metallic (granite) minerals[12]. A copper-molybdenum plant, operating since the 19th century, is located in Agarak city. The gold concentrate is also mined in the region. Building materials, furniture, canning, bakery, and confectionery industries are available in the city[13].

As in other rural areas of the RA, agriculture is one of the key factors of life support and survival here as well, but with fragmentation and a few agricultural lands owned by citizens, agricultural activity is not a product but a social factor. "Arevik" National Park, "Boghakar" and the southern part of "Shikahogh" State Reserves are in the community's territory, which are rich in unique fauna and flora, including species registered in the Red Book[14].

The area is rich in monuments of historical and cultural heritage. According to the state list of immovable historical and cultural monuments in the region, there are 17 defensive monuments (fortresses, towers, etc.) built from the 1st thousand BC to the XIX century, and the remains of 28 settlements from the XIX century, 34 simultaneous cemeteries, 22 churches built in the 10th and 18th centuries, ten mills and six bridges built in the 17th and 19th centuries, as well as khachkars of different periods, secular buildings, etc[15].

Natural, economic, cultural, recreational, and other resources can serve as the most vital development factors in the presence of human resources and the formation of the living environment necessary for the normal functioning of these resources. The proper territorial distribution of settlements and population, as well as the infrastructure's territorial allocation for the proper functioning of people, is vital.

Territorial distribution of settlements and population and transport connections

Fig. 2 shows the schematic representation of the territorial allocation of the region's settlements and inter-settlement relationships. The distance from the community center is shown by the internal number next to the names of the communities (in kilometers), and the higher number indicates the time it takes to traverse that distance (minutes). It is worth mentioning that the two settlements do not have a permanent population (Tkhkut and Aygedzor). Like these settlements, Tashtun, Lichk, and Nrnadzor villages have a somewhat isolated position.

At the same time, except for Meghri, Shvanidzor, Lehvaz, and Vardanidzor, practically all settlements in the community are in a dead-end situation and are not provided with alternative transport links with the outside world.

[11] Meghri Municipality. https://www.meghri.am/

[12] Armenian National Atlas, vol. A. "Geodesy and Cartography" State Non-Commercial Organization (SNCO), Yerevan, 2007. https://www.cadastre.am/news/atlasA

[13] Meghri Municipality. https://www.meghri.am/

[14] Syunik Regional Governor's Office. http://syunik.mtad.am/nature/

[15] Annex 9 of RA Government Decision No. 385-N "On approving the state list of immovable monuments of history and culture that are considered state property of the Republic of Armenia and are not subject to expropriation", dated 15.03.2007. Official Bulletin of the Republic of Armenia 2007.05.04/23.1 (in Armenian).

Our studies have shown that the dead-end location of settlements has a significant impact on their crowding [12]. In the Republic of Armenia, the population of dead-end rural settlements is 30-80% lower than the population of villages with alternative external connections, regardless of the location. The mentioned factor is of particular importance in the border regions, as it will determine the effectiveness of the evacuation of the population in emergency or war situations.

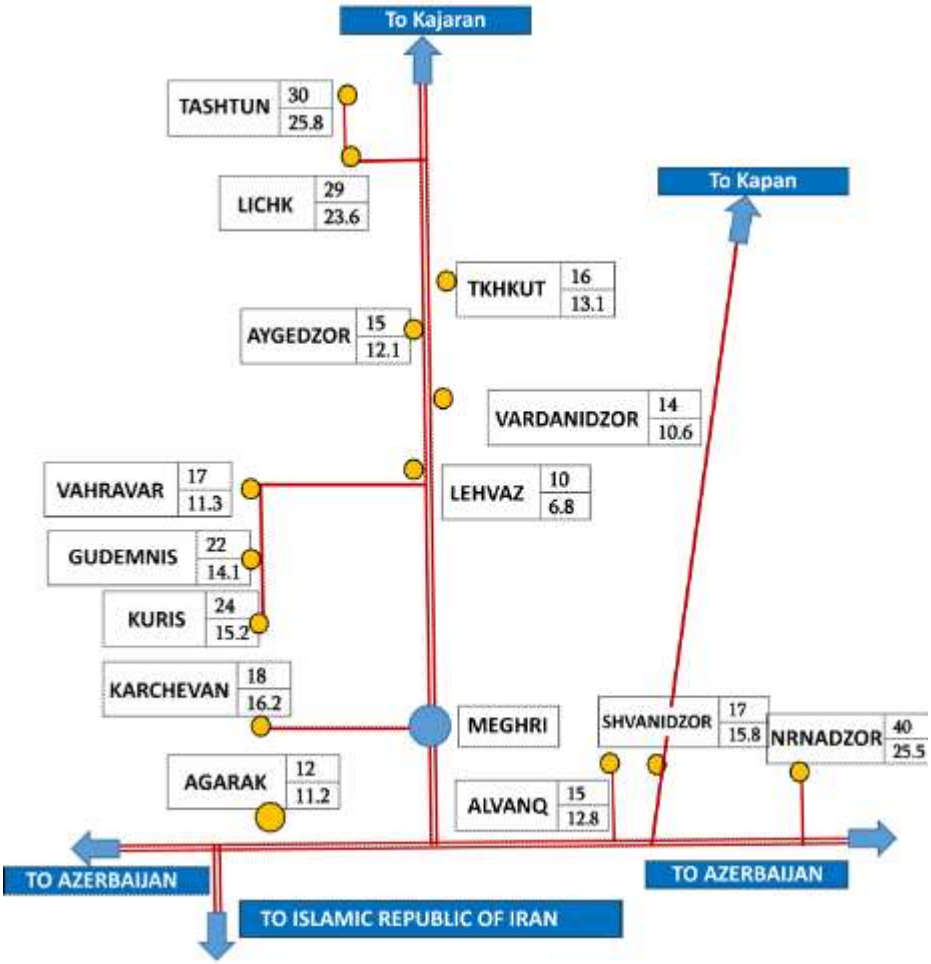

Fig. 2. *Territorial distribution scheme of the Meghri community*

This factor affected population dynamics, particularly in small villages (Fig. 3).

From 2001 to 2021, the population reduction was not observed only in the settlements next to the national and interstate roads (Vardanidzor, Lehvaz, Shvanidzor), which also have alternative transport links[16,17,18].

Furthermore, in terms of demographics, the most worrying situation is in Vahravar, Gudemnis, and Kuris villages, where the population is 30, 24, and 35 people, respectively[19]. If the current trends of population decline continue, these villages could become completely depopulated.

The Meghri community's five-year development plan for 2022–2026 was published[20] while this article was being written. It was found that in less than two years, Vahravar's population decreased by 3 people and made 27. In Gudemnis and Kuris, where 2 and 8 people remain, the situation is significantly worse.

[16] Statistical Committee of the Republic of Armenia. https://armstat.am/am/?nid=743
[17] Road map of the Republic of Armenia and the Republic of Artsakh. https://cadastre.am/storage/files/2018.jpg
[18] Statistical Committee of the Republic of Armenia. https://armstat.am/file/doc/99527423.pdf
[19] Statistical Committee of the Republic of Armenia. https://armstat.am/file/doc/99527423.pdf
[20] Meghri Community Five-Year Development Plan for 2022-2026 https://www.meghri.am/Pages/DocFlow/Def.aspx?nt=1&dt=Projects

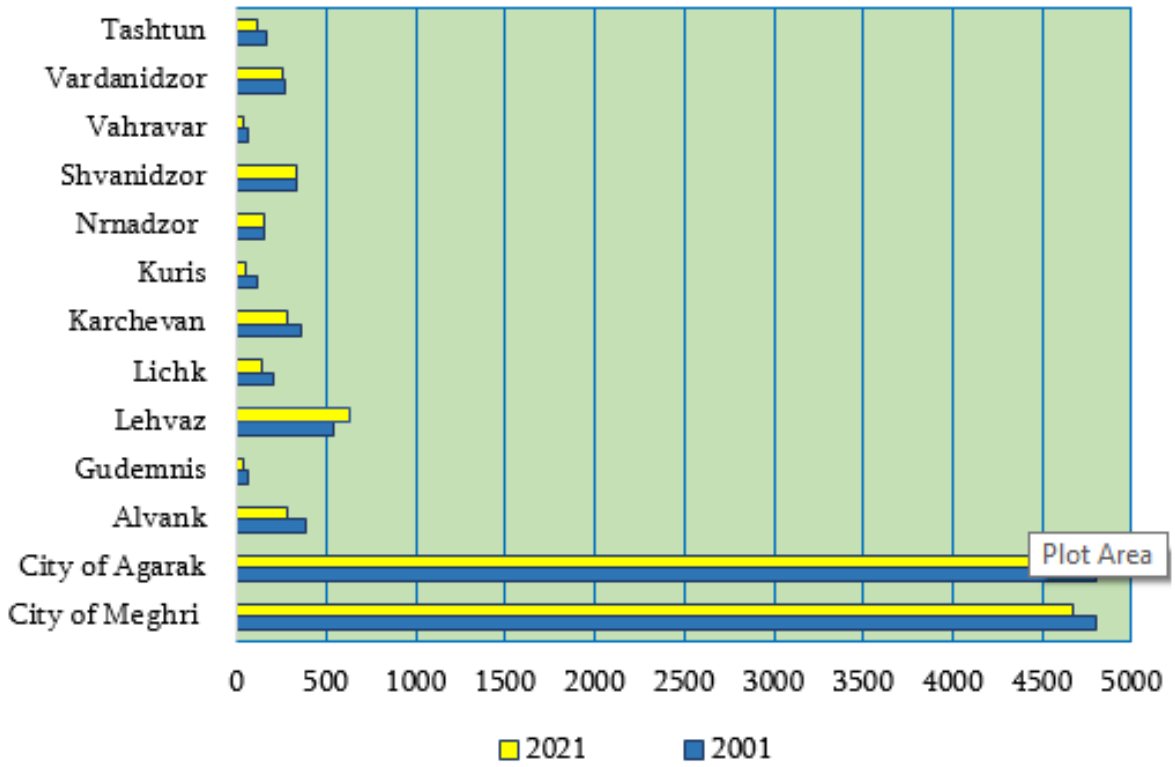

Fig. 3. *The dynamics of the population of the Meghri community in 2001-2021*

The solution to problems related to urban development is a necessary but not yet sufficient condition for the preservation of the most vital human resource in the region (and in general) and the cessation of emigration. To prevent the demographic catastrophe, let us touch upon some aspects of public policy (though not directly related to the subject of this study) in the following wordings.

The territorial distribution of infrastructures and the level of access to services

The level of access to public services is determined by the territorial distribution of settlements of various sizes, particularly in cities, because infrastructure for their provision cannot be provided in every settlement. The existence of infrastructure serving the primary needs of the population is vital in this sense.

Let us note, that when we refer to "primary needs," we do not mean the globally known set of indicators[21], which in the "Basic needs" includes food, primary healthcare, access to water and sanitation, safe shelter (including electricity), and basic education and quality health care are included in the "fundamentals of well-being". Moreover, it should be highlighted that this study bypassed the geographical distribution of infrastructures such as business, food, accommodation, and production facilities, the availability and effectiveness of wich are driven by the market and private sector investments. Problems related to the accommodation of higher education institutions, banks, notarial, and other services were also not studied, as we did not consider them as primary needs and access to which may exceed a 30-minute range.

Security, health, education, culture, and housing, as well as the infrastructures that provide emergency services to the latter, were considered the primary needs of the population. Among the primary needs, water and energy supply (electricity and gas) issues have a special place as mandatory components of livelihood. Without solving these problems, it is impossible to ensure the quality of life under any circumstances. In border regions, as a mandatory requirement, access to these services and alternative (reserved) possibilities of obtaining them should be considered.

[21] 2021. Social Progress Index / https://www.socialprogress.org/resources

Every settlement in Meghri has **electricity**. However, no settlement has a gas supply. Alternatives to the power supply are also nonexistent. Purchasing solar panels for kindergartens in Lehvaz, Shvanidzor, and Agarak is part of the five-year community development initiative[22]. However, this partial approach cannot be considered a complete solution to the problem, especially if we consider the fact that there are opportunities for wind energy use in the region[23].

The condition of the **water supply** cannot be considered sufficient either. Although the region is rich in water resources, the quality of drinking water is problematic. Due to the wear and tear of the water supply system, water losses reach large volumes, and frequent accidents lead to water pollution and deviations from sanitary norms. Like the daily regulation reservoirs, water supply networks need modernization or overhaul.

To clarify the scope of problems related to **population safety**, it should be noted that the traditional or "contact" methods for conducting wars are already being combined or even replaced by "non-contact" methods typical of "sixth generation" wars. In that case, non-traditional methods of warfare can play a crucial role (drones, the possibility of satellite positioning, infra and ultrasonic, electromagnetic, pulse, laser, and other types of weapons created using modern technologies) [13]. Therefore, modern technologies to counter the above weapons are of paramount importance, but this factor is the subject of research in another sphere. This research addresses the spatial placement of traditional civil or passive defense infrastructures directly related to spatial planning and aimed at population safety.

Access to health, education, sports, and cultural services, as required, was addressed based on the following principles:

a. Access components such as complete, up-to-date and reliable information about infrastructure, the availability of professional staff necessary for their provision, and the system of legal acts regulating the sectors have been bypassed. Only the availability of infrastructures and the time spent to use them were evaluated, in the case of individual infrastructures, also the possibilities of their alternatives,
b. Access of up to 15 min is mandatory in the case of the institutions under consideration for primary (polyclinic, outpatient) and emergency medical care, pre-school and primary schools, fire and rescue and emergency (water, power) services, civil defense facilities, and police,
c. 15-30 min of access is mandatory in the case of public schools, polyclinics, hospitals, health centers, clubs, culture houses or sports and cultural centers, and extracurricular institutions (technical, art, music, fine arts, sports schools, or educational centers),
d. Rcommendations on the territorial allocation of individual infrastructures will be presented by the principle of adding the "missing spheres".

The location of infrastructure for the primary needs of the population in settlements is shown in Fig 4.

Nrnadzor, Lichk, Tashtun, Vahravar, Gudemnis, and Kuris villages are the most vulnerable to public services. For the first three villages, the remoteness factor is problematic. For the remaining villages, the satisfaction factor of the population's basic needs and the complete lack of infrastructure is added to this factor.

Naturally, Meghri is practically provided with the main infrastructures that meet the primary needs of the population, and to some extent, also Agarak.

[22] Meghri Community Five-Year Development Plan for 2022-2026 https://www.meghri.am/Pages/DocFlow/Def.aspx?nt=1&dt=Projects

[23] Armenian National Atlas, vol. A. "Geodesy and Cartography" State Non-Commercial Organization (SNCO), Yerevan, 2007. https://www.cadastre.am/news/atlasA

Fig. 4. *Infrastructure serving the basic needs of the population in the settlements of the Megri community*

Results and Discussion

One of the main issues in the border areas is to ensure the **population's physical security**, which implies the availability of hiding places and bomb shelters equipped with means that meet the regulatory requirements for strength and reliability. Theoretically, the optimal option would be to include such opportunities in every building that can serve people, but from the standpoint of implementation, this appears improbable given the high expense and low social status of the beneficiary subject. The construction of centralized shelters, particularly in small communities, may appear to be the most effective solution, but here, the probability to locate them and vulnerability risks increase to a certain level. The most efficient way to construct a network of bomb shelters may be to make them accessible to relatively large groups of people in or near the objects of particular importance, ensuring people's placement in the shortest possible time and facilitating the solution of various organizational issues.

Among other means necessary for life support, in the shelters the provision of water and power supply with backup facilities should be considered mandatory. Given the industry specifics, we will refrain from offering targeted networking options. As passive defense measures, one can also consider the establishment of green fences and forest strips, limiting the visibility of rivals not only outside but also inside the settlements, as well as measures to cover the light of the structures from potential danger. Finally, with newly built facilities, it should be a mandatory normative requirement to provide shelters or hiding places, depending on the facility.

As we have already mentioned, in any border region, it is necessary to form alternative transport connections with the outside world, considering the problem of filling their "missing links" as a priority of

spatial planning. However, it is impossible to propose theoretically effective and practically complete options for solving the problem of dead-end villages in mountainous regions because of natural factors (broken relief and large slopes) and existing geopolitical realities. Nevertheless, it is possible to provide alternatives to external contacts that can partially mitigate this issue.

In particular, it is possible to solve this problem in the Meghri community with the scheme shown in Fig. 5. Accordingly, to fill the missing links on the highways, it is necessary to:

- modernize and overhaul Meghri-Karchevan and Karchevan-Kuris roads that were built but currently are unfit for operation, creating alternative connections for Gudemnis and Vahravar,
- to build a new road in the northern part of Tashtun, connecting it with the interstate highway,
- to build new highways that connect Nrnadzor-Shvanidzor and Alvank-Shvanidzor, giving these communities the option for external connections. It should be noted that the mentioned parts contain ground roads, which might be considered while creating design documentation.

Fig. 5. *Meghri region's alternative transportation link formation scheme*

It follows from the picture of the territorial distribution of infrastructures serving public services, presented in Fig. 4, that a relatively effective way of filling the missing links can be the formation of the following four bunches to ensure the primary needs (Fig. 6):

a. Shvanidzor bunch, providing up to 15 min of accessibility for the residents of Nrnadzor and Alvank. This option is possible only by constructing the Nrnadzor-Shvanidzor and Alvank-Shvanidzor roads shown in Fig. 3, because with the current road network, it is possible to reach Shvanidzor from Nrnadzor in 27 min.,

b. Lehvaz bunch, providing up to 15 min of access for residents of Vardanidzor, Vahravar, Gudemnis, and Kuris,
c. Meghri bunch, which will also include Agarak city and Karchevan village. From the standpoint of meeting basic needs, this bunch now can practically access all the services we consider primary,
d. Lichk bunch including Tashtun village. Note that providing access to services is a difficult task in this bunch from the perspective of economic efficiency. Nevertheless, it is possible to place infrastructures of at least minimum volume and quantity in Lichk, otherwise, the development prospects of these villages may be challenging.

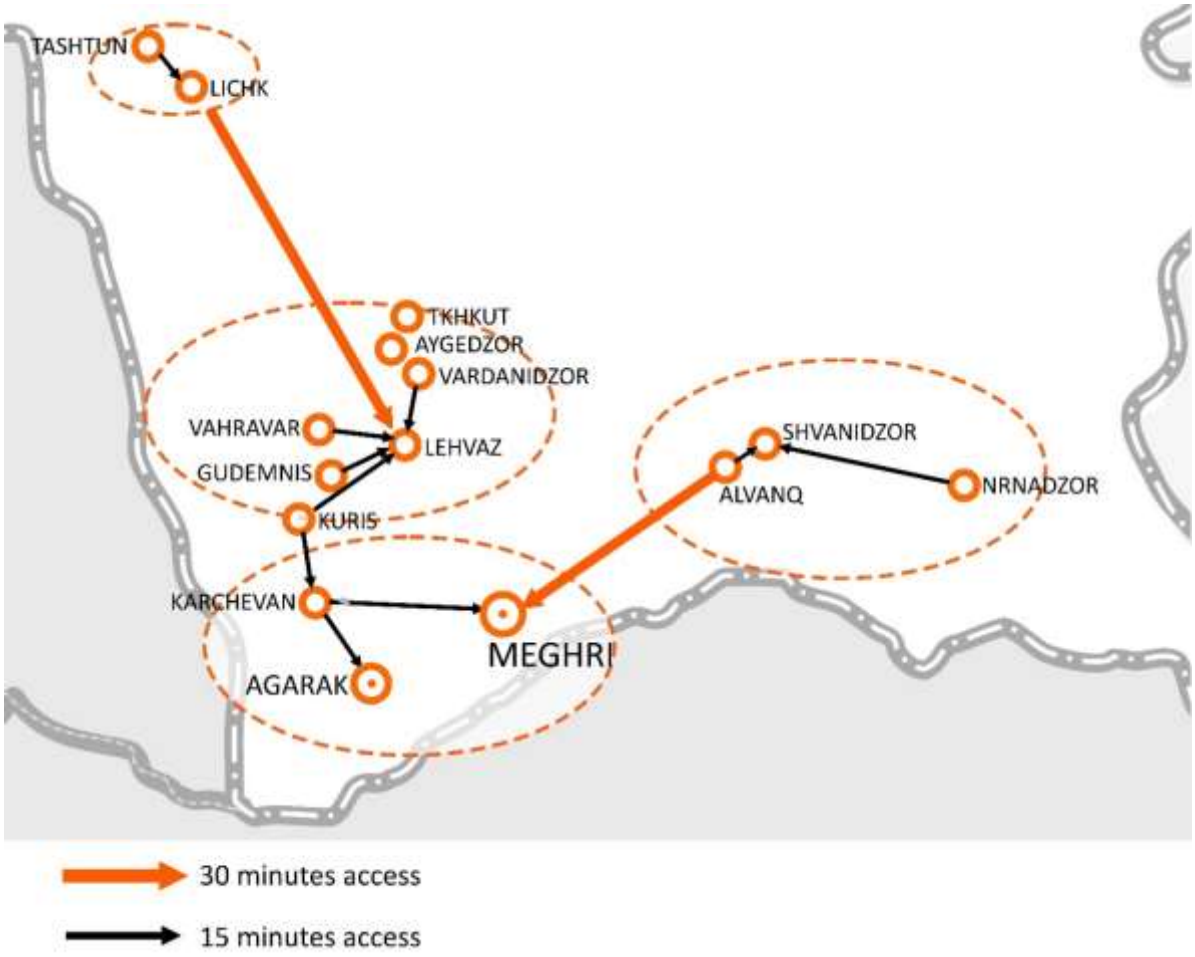

Fig. 6. *Proposed option for access to services serving the primary needs of the population*

In case of formation of the mentioned bunches, the problem of infrastructures assuming access of up to 30 minutes is also resolved by forming Meghri-Shvanidzor and Lichk-Lehvaz links.

Conclusion

The following concepts of spatial planning must be put into operation to ensure the security of the residential areas in border regions and other settlements where conflict is a continual threat:

1. Creating a network of passive protection infrastructures that will be available to all residents,
2. Creation of alternatives for external road transport connections for all settlements, excluding the cul-de-sac position of the settlements,
3. Designing a duplicated water and energy supply system,

4. Completing the missing links of the infrastructure necessary to meet the primary needs of the population requires merging them in certain settlements to ensure their access to the residents of all settlements, moreover:
   - Provision of up to 15 min of access to primary and emergency medical care, pre-school institutions and elementary classes, fire, rescue, and emergency (water supply, energy supply) services, civil defense facilities, and the police,
   - Provision of up to 30 min of access to schools, polyclinics, hospitals, health centers, clubs, culture houses, sports and cultural centers, and extracurricular institutions (technical, art, music, fine arts, sports schools, or educational centers).

With all this, as we have already mentioned, the application of the listed spatial planning principles is a necessary but not a sufficient condition for protecting the most important resource - people - and the prevention of population outflow. To solve this issue, it is also necessary to apply other sectoral measures of state policy, starting from exempting the rural population and business executives from all taxes, to subsidizing individual programs and applying grants.

The implementation of the mentioned measures is especially important for the Meghri community, considering its strategic importance.

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